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COMIDA: A RADIONUCLIDE FOOD CHAIN MODEL FOR ACUTE FALLOUT DEPOSITION

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ABSTRACT

A dynamic food chain model and computer code, named "COMIDA," has been developed to estimate radionuclide concentrations in agricultural food products following an acute fallout event. COMIDA estimates yearly harvest concentrations for 5 human crop types (Bq kg^{-1} crop per Bq m^{-2} deposited) and integrated concentrations for 4 animal products (Bq d kg^{-1} animal product per Bq m^{-2}) for a unit deposition that occurs on any user-specified day of the year. COMIDA is structurally very similar to the PATHWAY model and includes the same seasonal transport processes and discrete events for soil and vegetation compartments. Animal product assimilation is modeled using simpler equilibrium models. Differential transport and ingrowth of up to three radioactive progeny are also evaluated. Benchmark results between COMIDA and PATHWAY for monthly fallout events show very similar seasonal agreement for integrated concentrations in milk and beef. Benchmark results between COMIDA and 4 international steady-state models show good agreement for deposition events that occur during the middle of the growing season. COMIDA will be implemented in the new Department of Energy (DOE) version of the MELCOR Accident Consequence Code System (MACCS2) for evaluation of accidental releases from nuclear power plants.

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1. INTRODUCTION

Radionuclide fallout on agricultural systems can be a significant pathway for dose to humans via ingestion of contaminated crops and animal products. The fallout may occur as a result of routine atmospheric emissions from nuclear facilities, nuclear weapons testing, or accidents involving atmospheric release of radioactive material. Mathematical models that predict radionuclide transport in the food chain and resulting human ingestion doses have been developed for dose reconstruction of past fallout events and for prospective assessments required for regulatory compliance, facility design, and safety analyses. Many of the food chain models currently in use employ equations similar to those used in U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (1977), which assume a chronic release scenario and equilibrium conditions between vegetation, soil, and animal products. These "quasi-equilibrium models" do not account for daily changes in plant biomass, livestock feeding regimes, or ingrowth and differential uptake of radioactive progeny during food chain transport. They are generally not appropriate for assessment of critical short-term impacts from acute fallout events that may occur during different times of the year.

We have developed a dynamic food chain model and computer code, named COMIDA, to support the new U. S. Department of Energy (DOE) version of the MELCOR Accident Consequence Code System (MACCS) (Jow et al. 1990), a severe reactor accident environmental code. COMIDA was developed for the following reasons:

1. A single MACCS run evaluates many randomly-selected fallout dates during a calendar year. A dynamic food chain model was needed that could, with one input file, evaluate the resulting variations in radionuclide concentrations in foods that will occur due to the temporal relationships between fallout, current plant biomass, and site-specific discrete agricultural events such as tillage, planting, and harvest. Although well-established dynamic food chain models exist (Whicker and Kirchner 1987), none were found that could be easily interfaced with MACCS.

2. The MACCS code requires a food chain model that predicts radionuclide *concentrations* in a wide variety of food products at selected annual intervals after an acute deposition. Yearly food product concentrations and the resulting ingestion doses can be used for decisions on mitigative actions, such as deep plowing and food product disposal. In general, most food chain models are integrated into code packages that either do not output individual food product concentrations from specific pathways or do not allow selection of different integration times.

3. A model was needed to account for the in-growth and environmental transfer of radionuclide progeny after deposition. COMIDA evaluates up to 3 progeny for each parent radionuclide and allows input of either parent or progeny element-specific parameter values. Therefore, progeny that may behave differently than their parent in the environment (e.g. $^{99}Mo \rightarrow ^{99m}Tc$) can be simulated using their own properties.

4. A model was needed that has simple input data requirements, is easy to operate, and is fully transportable. COMIDA requires 2 relatively small input files: a nuclide-specific variable input file and a site- and scenario-specific parameter input file. These parameters are obtained or derived from data commonly reported in the literature and may be developed for diverse site locations. COMIDA is written in FORTRAN 77 and operates on a personal computer with a DOS operating system or a UNIX based workstation.

2. MODEL DESCRIPTION

2.1 Output

For a unit acute fallout deposition, COMIDA estimates radionuclide concentrations in human crops at yearly harvest intervals (Bq kg^{-1} crop per Bq m^{-2} deposition) and integrated concentrations in animal products (Bq d kg^{-1} animal product per Bq m^{-2}). Five different crop types are simulated: leafy vegetables, root vegetables, grain, fruit, and legumes. For animal products, COMIDA calculates integrated concentrations in milk, beef, poultry, and a user-defined "other animal" (e.g. pork, lamb). Four animal feed sources are evaluated--pasture grass, hay, grain, legumes (soybeans)--in addition to soil ingestion. Animal product concentrations from each feed source are provided for any selected 365-d human consumption period(s) after the accident in addition to a cumulative total (e.g. year 1, year 5, and 0 to 5 y). For milk, a short-term (less than 1 y) integration time may also be selected.

2.2 Conceptual Model

A generalized conceptual representation of the COMIDA model is shown in Fig. 1. The model is very similar to the PATHWAY model developed by Whicker and Kirchner (1987) for assessment of weapons test fallout in southeastern Utah. Time-variable concentrations are dynamically modeled for 5 compartments--vegetation surface (Qvs), vegetation internal tissues (Qvi), surface soil (Qss), labile (active root zone) soil (Qrs), and fixed soil (Qfs). The depths of Qss and Qrs are user-specified to account for different site characteristics. The vegetation/soil model is used to calculate: (1) human crop inventories at harvest; (2) integrated pasture grass inventories while animals are grazing; (3) harvested animal feed storage inventories; and (4) integrated surface soil inventories for animal soil ingestion.

For simplicity and due to lack of biological elimination rate data for all radionuclides and animal products, the model does not dynamically treat the transfer of activity between vegetation/surface soil and animal products. Rather, it assumes that animal product concentrations are some equilibrium fraction of the time-variable pasture grass, stored feed,

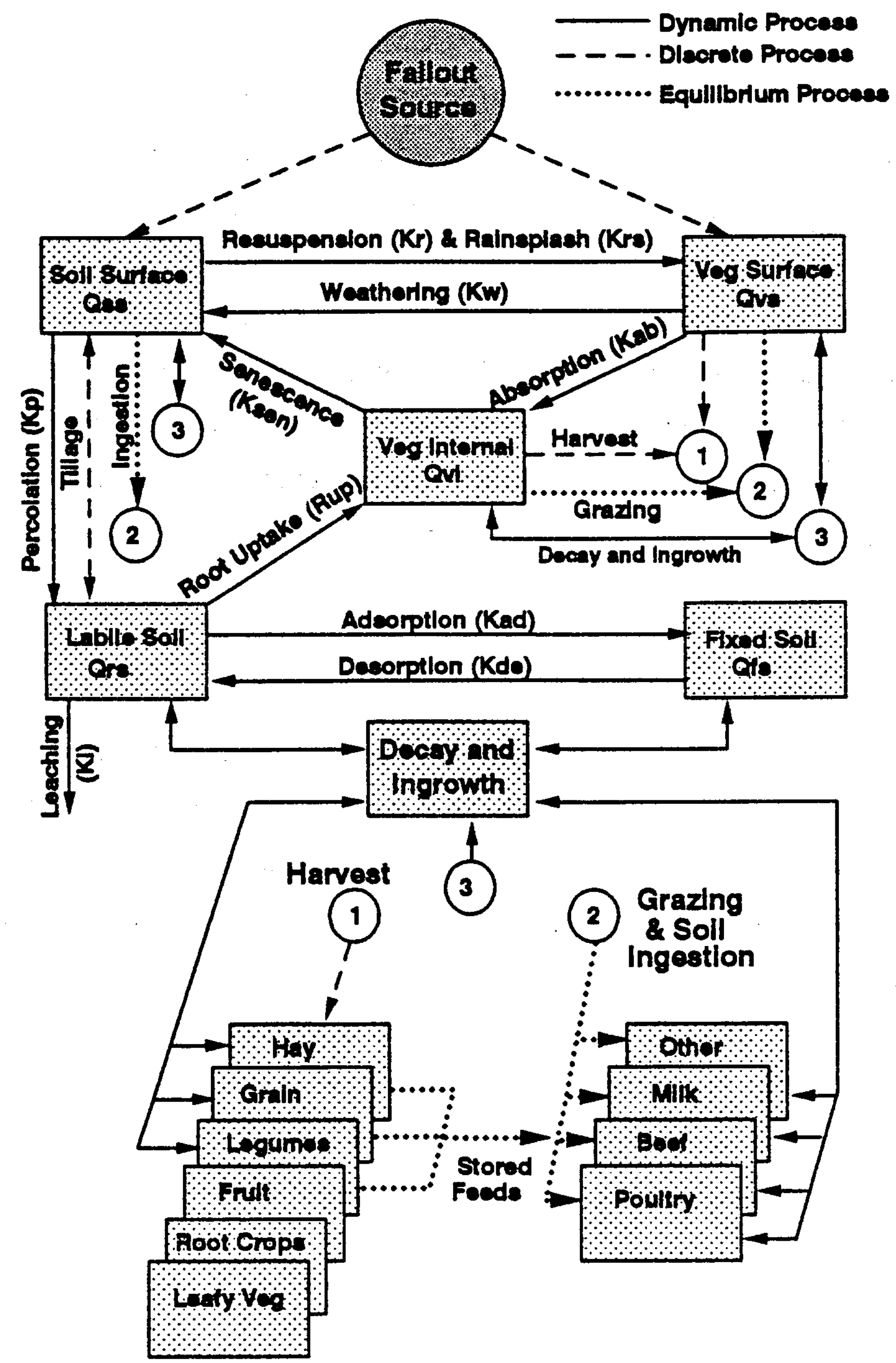

Figure 1. Conceptual Model for the COMIDA food chain model.

and surface soil concentrations. This is accomplished using published values for the feed-to-animal product *transfer coefficient* which is the fraction of the daily intake of a specific radionuclide (or element) that is transferred to a particular animal product at equilibrium. In addition, the model assumes negligible depletion of the pasture grass and surface soil compartments by grazing. These assumptions introduce a conservative bias in the model, especially for radionuclides that are not rapidly equilibrated in animal products or for areas with high livestock density. However, the calculated animal product concentrations are still considered to be more realistic than those estimated by simple equilibrium models because they are a function of the time-variable vegetation and soil compartment concentrations.

In order to explicitly treat the ingrowth and differential transport of radioactive progeny, an additional set of modeling compartments are defined for each decay chain member (4 members, including parent, maximum). Each decay chain model is identical to that shown in Fig. 1 with the addition of transport (ingrowth) from each parent compartment to the same progeny compartment. The model therefore evaluates up to 20 compartments--5 compartments (Qvs, Qvi, Qss, Qrs, Qfs) for each of the 4 decay chain members.

2.2 Modeling Kinetics

COMIDA's vegetation and soil model simulates both continuous and discrete transport processes in order to move radioactivity between modeling compartments. The continuous processes are assumed to be first-order where the rate of transfer of radioactivity from a compartment is proportional to the amount of radioactivity remaining in that compartment. As such, they may be described mathematically by a rate constant which is the fraction of radioactivity that is removed from a compartment per unit time (units of time^{-1}). Except for the root uptake process, the rate of transfer of radioactivity between compartments (in Bq m^{-2} d^{-1}) is calculated by the product of the current radioactivity in the source compartment (Bq m^{-2}) and the rate constant (d^{-1}). Root uptake rate (R_{up}) is assumed to be a function of the plant growth rate (dB/dt) which is calculated in COMIDA using a logistic biomass growth model. The time rate of change of radioactivity in a particular compartment (dQ/dt, in Bq m^{-2} d^{-1}) may be described by a first order differential equation that is simply the sum of the rates into that compartment minus the sum of the rates out of that compartment:

$$\textit{Vegetation surface}(Qvs):\quad \frac{dQvs}{dt} = (Kr + Krs)\,Qss - (Kw + \lambda + Kab)\,Qvs \tag{1}$$

$$\textit{Vegetation internal}(Qvi):\quad \frac{dQvi}{dt} = Kab\,Qvs + R_{up} - (\lambda + Ksen)\,Qvi \tag{2}$$

$$\textit{Surface soil}(Qss):\quad \frac{dQss}{dt} = Kw\,Qvs - (Kr + Krs + Kp + \lambda)\,Qss \tag{3}$$

$$\textit{Labile soil}(Qrs):\quad \frac{dQrs}{dt} = Kp\,Qss + Kde\,Qfs - (Kl + Kad + \lambda)\,Qrs - R_{up} \tag{4}$$

$$\textit{Fixed soil}(Qfs):\quad \frac{dQfs}{dt} = Kad\,Qrs - (Kde + \lambda)\,Qfs \tag{5}$$

where

Kr = resuspension rate constant (d^{-1})

Krs = rainsplash rate constant (d^{-1})

Kw = weathering rate constant (d^{-1})

λ = decay rate constant (d^{-1})

Kab = foliar absorption rate constant (d^{-1})

R_{up} = root uptake rate (Bq kg^{-1} d^{-1})

Ksen = senescence rate constant (d^{-1})

Kp = percolation rate constant (d^{-1})

Kde = fixed soil desorption rate constant (d^{-1})

Kl = leach rate constant (d^{-1})

Kad = fixed soil adsorption rate constant (d^{-1})

In order to evaluate progeny ingrowth, COMIDA evaluates compartment concentrations in terms of atoms rather than radioactivity. To do this, the initial fallout concentrations in the Qvs and Qss (Bq m^{-2} d^{-1}) compartments are converted to atoms m^{-2} by dividing by λ (d^{-1}). Prior to output, COMIDA converts atom concentrations back to activity concentrations by multiplying by λ. The equations for radioactive progeny (decay chain member *j*) are the same form as eqns. (1) - (5) with the addition of an ingrowth term from the parent (decay chain member *j-1*). For example, the equation describing the time rate of change of atoms in the surface soil compartment for progeny *j* ($dNss_j/dt$) is

$$\frac{dNss_j}{dt} = KwNvs_j - (Kr + Krs + Kp + \lambda_j)Nss_j + \lambda_{j-1}Nss_{j-1} \tag{6}$$

Numerical integration of these compartments is accomplished in COMIDA through the implementation of a fourth order Runge-Kutta routine with adaptive stepsize control (Press et al. 1987). The adaptive stepsize control allows the routine to select the optimum time step to take between integration limits. The integration limits are defined between various discrete events (e.g. fallout, tillage, harvest dates) as input by the user.

2.3 Code Implementation

COMIDA is written in FORTRAN 77 and implemented on a personal computer with an DOS operating system. The source code, with minor modification, is compatible with most FORTRAN compilers on UNIX operating systems. Input to the code is through two, free format ASCII files, one with site- and scenario-specific values and one with nuclide-specific values (see **APPENDIX**). Output is written to two ASCII files. The first file contains a formatted listing of selected output. The second file contains a dump of intermediate calculated values which can be useful for benchmark purposes or in understanding the code.

3. TRANSPORT PROCESSES

The following discussion describes suggested or previously used methods and parameter values that can be used to calculate the rate constants needed for COMIDA input. Alternative methods may be employed by the user, and appropriate site-specific values are recommended.

3.1 Resuspension (Kr)

Wind transport of deposited radioactivity from surface soil to vegetation surfaces is simulated using a resuspension rate constant, which is the fraction of surface radioactivity removed per unit time. Values for Kr range from 10^{-7} to 10^{-1} d^{-1} (10^{-12} to 10^{-6} s^{-1}) for various locations, particle types, and wind speeds (Healy 1980; Sutter 1982). A value may also be calculated from the product of a resuspension factor (RF, m^{-1}) and deposition velocity (V, m d^{-1}). RF values range from 1×10^{-10} to 1×10^{-2} m^{-1}, depending on the location, source material, and type of resuspension stress (Sutter 1982). A Kr value of 1.7×10^{-3} d^{-1} was used in the PATHWAY model and is based on a RF of 1×10^{-5} m^{-1} for Utah farm areas and an average deposition velocity 173 m d^{-1}. More recent measurements from the Chernobyl experience indicate lower initial RF values ranging from 3.6×10^{-9} to 4.9×10^{-8} m^{-1} for European climates (IAEA, 1992).

3.2 Rainsplash (Krs)

In addition to resuspension by wind, rainsplash may be a significant process for resuspension of radionuclides from the surface soil to vegetation surfaces, especially for low-lying foliage (less than 40-cm high) or areas with intense rainstorms (Dreicer et al. 1984). To simulate this process for rangeland and agricultural areas in Southwestern Utah, PATHWAY derived a value of 8.6×10^{-4} d^{-1} from experimental data (Dreicer 1984). For human crops, COMIDA sets the rate constants for resuspension and rainsplash to 0 before and after the growing season.

3.3 Weathering (Kw)

This process moves radioactivity from vegetation surfaces to the soil surface as a result of wind and water removal, growth dilution, and herbivorous grazing. A value of $4.95 \times 10^{-2}\ d^{-1}$ is generally used for all radionuclides except radioiodine, which is removed at a faster rate of $8.67 \times 10^{-2}\ d^{-1}$ (Miller and Hoffman 1983).

3.4 Foliar Absorption (Kab)

Surficial contamination on plant foliage may be absorbed internally and, therefore, not be affected by the weathering process. This process is more dominant early after fallout while root uptake becomes increasingly more important with time. The formulation used in PATHWAY to calculated Kab is

$$Kab = \frac{fa\,Kw}{1-fa} \tag{7}$$

where

fa = fraction of a surface deposit that is absorbed

Foliar absorption generally increases with element solubility. The following values for Kab were estimated for PATHWAY:

$1.0 \times 10^{-3}\ d^{-1}$ for Sr, Ba (Middleton 1960)
$5.5 \times 10^{-3}\ d^{-1}$ for Cs, Te, Mo (Middleton 1960; CEC 1979)
$8.5 \times 10^{-3}\ d^{-1}$ for I (Hungate 1963)
$0\ \ d^{-1}$ for Ru, Ce, Zr, Rh, Nd, Np, Pu (relatively insoluble)

Other elements may be estimated based on their relative solubilities. In COMIDA, foliar adsorption is active only during the user defined growing season; otherwise, the rate constant is set to zero.

3.5 Pasture Senescence (Ksen)

Senescence transports biomass from aging pasture vegetation to soil after the growing season is completed. Since weathering rapidly reduces the vegetation surface inventory, senescence is practically treated in COMIDA by first-order transfer of internal vegetation radioactivity to the pasture soil at the end of the livestock grazing season (TEL). Biomass is discretely reduced to a user-defined minimum value on 1 January of the following year. The senescence rate constant may be calculated based on the assumption that 99.9% of the inventory in the plant will fall to the soil between TEL and 31 December (10 half-times):

$$Ksen = \frac{\ln 2}{T_s} \tag{8}$$

where

T_s = senescence half-time = 0.1(number of days from TEL to 31 December) (d)

3.6 Percolation (Kp)

This physical process transfers radioactivity from the surface soil to the labile soil compartment, thereby decreasing the surface soil inventory and, as a result, the rate of resuspension to plant surfaces. PATHWAY uses a first-order rate constant of $1.98 \times 10^{-2}\ d^{-1}$ which is based on a 35-d half-time observed for declines in resuspension (Langham 1972; Anspaugh et al. 1975).

3.7 Soil Adsorption (Kad) and Desorption (Kde)

Many elements may become fixed in soil by adsorption to clay particles thereby making them less available for root uptake (Schulz 1965). For most of these elements, the fixation process is fairly rapid and is generally accounted for in model simulation by low observed plant-to-soil concentration ratios. However, ^{137}Cs has been observed to become increasingly unavailable for root uptake over longer periods of time. In one 5-y growth experiment (Squire and Middleton 1966), root uptake of ^{137}Cs decreased by approximately 90% in four soils ranging from 3.2% to 19.5% clay. To simulate Cs fixation, both PATHWAY and COMIDA use first order adsorption and desorption rate constants (Kad, Kde) between the labile soil compartment, where root uptake occurs, and a fixed soil compartment, where root uptake does not occur. PATHWAY assigned Kad and Kde values of 1.9×10^{-3} d^{-1} and 2.1×10^{-4} d^{-1} respectively, which removes approximately 90% of the Cs from the labile soil compartment after a 5-y period. For these processes, radioactive progeny are assumed to behave similar to the parent, and therefore, the same rate constants are used.

3.8 Soil Leaching (Kl)

Leaching moves radioactivity from labile root zone soil to deep soil where it is unavailable for root uptake. This is a long-term process and is, therefore, based on annual average parameter values. A leach rate constant (Kl_j, d^{-1}) for decay chain member j may be calculated by (Baes and Sharp 1983):

$$Kl_j = \frac{P + I - E - R}{\theta \, Xrs \left[1 + \frac{\rho \, Kd_j}{\theta} \right]} \tag{9}$$

where

P = annual average total precipitation (m d^{-1})

E = annual average evapotranspiration (m d^{-1})

I = annual average irrigation (m d^{-1})

R = annual average surface runoff (m d^{-1})

Xrs = depth of labile soil layer (m)

θ = annual average volumetric water content of the soil layer, xr (m^3 m^{-3})

ρ = soil bulk density (g cm^{-3})

Kd_j = soil-water distribution coefficient for decay chain member j (Ml g^{-1})

Element-specific Kd values are given by Baes et al. (1984); therefore, a nuclide-specific Kl value must be calculated for each decay chain member and input into COMIDA by the user.

3.9 Radioactive Decay and Ingrowth (THALF)

This process decays and in-grows radioactivity in all model compartments. COMIDA calculates the radionuclide decay constants for up to four decay chain members based on the user input of half-life (THALF).

3.10 Tillage

Tillage is a discrete process that transfers radioactivity on the surface soil into deeper soil layers, where it cannot be resuspended or splashed onto vegetation. This process may significantly reduce concentrations on crops if the fallout occurs just prior to the tillage date. COMIDA accounts for tillage at a user-specified tillage date (TT) by redistributing the total radioactivity in the surface (Qss) and labile soil (Qrs) compartments according to the relative mass of soil in each compartment (Whicker and Kirchner 1987):

$$Qrs = (Qss + Qrs)\left(\frac{Mrs}{Mss + Mrs}\right) \quad when\ t = TT \tag{10}$$

where

Mss = mass of surface soil (kg m^{-2}) = Xss (m) Pss (kg m^{-3})

Mrs = mass of labile soil (kg m^{-2}) = Xrs (m) Prs (kg m^{-3})

4. PLANT GROWTH MODEL

COMIDA uses a logistic growth model (Odum 1971) to estimate time-variable plant biomass and growth rate. The plant growth rate at each time step is used to calculate the root uptake rate from the soil to the internal vegetation compartment. The current plant biomass at the deposition date is used to calculate the fraction of fallout allocated between vegetation and soil compartments.

The change in biomass as a function of time (dB/dt in dry kg m^{-2} d^{-1}) is given by

$$\frac{dB}{dt} = Kg\,B\left(\frac{BMAX-B}{BMAX}\right) \qquad (11)$$

where

Kg = growth rate constant for crops, pasture (0.12 d^{-1}) and hay (0.27 d^{-1}) (Whicker and Kirchner 1987)

B = the current biomass (kg dry m^{-2})

BMAX = maximum edible crop biomass (kg dry m^{-2})

Eqn. (11) may be solved in terms of B to give plant biomass as a function of time [B(t)]:

$$B(t) = \frac{BMAX}{1 + e^{a-Kgt}} \quad and \quad a = \ln\left(\frac{BMAX-BI}{BI}\right) \qquad (12)$$

where

BI = initial biomass for crops and grain (0.015 kg m^{-2}, dry) and minimum winter biomass for pasture (0.07 kg m^{-2}, dry) and hay (0.08 kg m^{-2}, dry) (Whicker and Kirchner 1987)

a = constant of integration defining the position of the curve relative to the origin (unitless)

As can be seen in Fig. 2, the rate of increase in biomass (growth rate) and the general shape of the growth curve are dependent upon the value assigned for the growth rate constant (Kg) in addition to the values assigned for BI and BMAX.

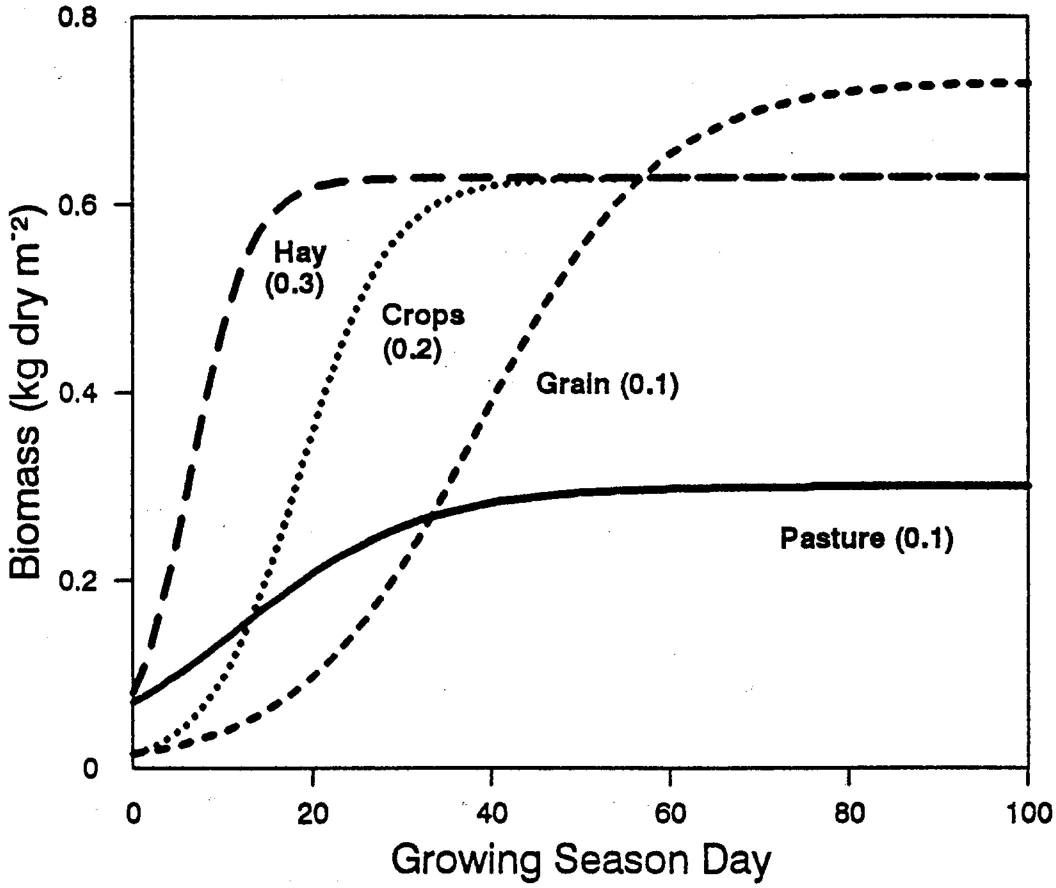

Figure 2. COMIDA uses a logistics growth model to calculate daily plant biomass during the growing season.

Plant biomass is calculated in COMIDA only during the growing season. From 1 January to the start of the growing season, the biomass is assumed to be at a user-defined minimum value (BI). After the pasture growing season until the end of the year, biomass is allowed to remain at its maximum value, although the model dynamically treats loss of radioactivity from pasture to soil via senescence (Ksen) during this time. Loss of biomass due to animal grazing is not accounted for.

4.1 Interception Fraction (FV)

An empirical relationship developed by Chamberlain (1970) is used in COMIDA to calculate the fraction of total fallout that is intercepted and initially retained on vegetation surfaces (FV).

$$FV = 1 - e^{-\alpha B(t)} \tag{13}$$

where

B(t) = standing crop biomass at the time of deposition (Bq kg^{-2}, dry)

α = foliar interception constant (m^2 kg^{-1}), measured as the ratio of vegetation concentration (Bq kg^{-1}) to the total deposition (Bq m^{-2})

Using this formulation, a time-variable interception fraction is calculated which depends on the amount of biomass that is present at the time of deposition (B[t], eq. 12). Chamberlain's relationship applies to the entire exposed, above-ground plant (not just the edible parts); therefore, COMIDA requires user-input values for maximum *standing* biomass (BSTAND) for each vegetation type in order to calculate B(t) in this case. The foliar interception constant (α) can be considered to vary as a function of vegetative surface area as well as the fallout particle size, type of deposition (wet vs. dry), and the physicochemical form of the contamination (Hoffman et al. 1984; Hoffman et al. 1992; Pinder 1988). PATHWAY used an α value of 0.39 m^2 kg^{-1} for the larger particulate fallout associated with weapons testing (Romney et al. 1963; Anspaugh et al. 1986). For general safety assessments of fallout smaller than a few micrometers, an α value of 3 m^2 kg^{-1} is suggested for all vegetation except fruit based on grass canopy (Miller 1980) and corn plants measurements (Pinder et al. 1988). Observed interception fractions for orange trees (Pinder et al. 1987) suggest a lower α value of 0.3 m^2 kg^{-1} for the fruit category.

During the growing season, the fraction of fallout that is allocated to the soil surface (FS) is 1-FV. For deposition on crops prior to the crop growing season, 100% of the fallout is assumed to go to the surface soil compartment (FS = 1). For depositions on hay and pasture prior to the growing season, the interception fraction is calculated using the minimum biomass (BI). For depositions that occur after the crop growing season or livestock grazing season, 100% of the fallout is assumed to go to the surface soil compartment.

4.2 Root Uptake Rate

COMIDA uses a formulation presented in PATHWAY to calculate the rate of uptake into edible parts of plants (R_{up}, in Bq m^{-2} d^{-1}). This formulation is based on the assumption that root uptake is directly related to plant growth rate (dB/dt) and a plant-to-soil concentration ratio (CR):

$$R_{up_{ij}} = \frac{Qrs_{ij}(dB/dt)_i CR_{ij}}{Xrs\ Prs} \tag{14}$$

where

Qrs_{ij} = radioactivity in labile soil compartment for crop type *i* and decay chain member *j* (Bq m^{-2})

CR_{ij} = concentration ratio for plant type *i* and decay chain member *j* (Bq g^{-1} dry plant per Bq g^{-1} soil)

Xrs = depth of labile soil compartment (m)

Prs = bulk density of labile soil (kg m^{-3})

Radioactivity uptake into plants is, therefore, time-variable depending upon the seasonal plant growth rate, dB/dt. For root uptake into human crops, COMIDA uses a growth rate that is calculated using maximum *edible* biomass or yield (BMAX).

The concentration ratio is dependent on the physicochemical form of the radionuclide, plant species and location within the plant (leaves vs. seeds), soil, and other factors. For each radionuclide decay chain member, COMIDA allows input of site-specific CR values for each of the five human crop types, pasture grass, and hay. Baes (1984) has compiled element-specific concentration ratios for vegetative (B_v) and non-vegetative (reproductive) (B_r) portions of plants. If these values are used in COMIDA, the B_v value is appropriate for leafy vegetables, pasture grass, and hay, while the B_r value should be used for all other human crops (grains, root vegetables, fruits, and legumes). A detailed compilation of CR values for various crops, soils, and contamination scenarios has been published by the International Union of Radioecologists (1989).

5. CALCULATION OF FOOD PRODUCT CONCENTRATIONS

5.1 Human Crop Concentrations at Harvest

The total edible crop concentration for crop type i and decay chain member j (QC_{ij}, in Bq wet kg^{-1}) is calculated at harvest by

$$QC_{ij}(TEC) = \left(\frac{Qvs_{ij}(TEC)\, TVC_i + Qvi_{ij}(TEC)}{BMAX_i} \right) FD_i \qquad (15)$$

where

Qvs_{ij} =	concentration on vegetation surfaces at harvest (Bq m^{-2})
Qvi_{ij} =	concentration in edible vegetation tissue at harvest (Bq m^{-2})
TVC_i =	transfer factor from exposed to edible surfaces for human crops (unitless)
$BMAX_i$ =	edible crop biomass at harvest (yield) (dry kg m^{-2})
FD_i =	ratio of dry to wet weight (unitless)
TEC =	time of crop harvest (Julian day)

The vegetation surface concentration is multiplied by the fraction that is deposited on edible tissues of human crops (TVC) to account for surface layers that are removed prior to ingestion (e.g. corn husks). Currently, TVC is assumed to be 1 for leafy vegetables and 0.1 for all other human crops (Napier et al. 1988). The user may select any number of years for which harvest concentrations are calculated. For these harvest concentrations to be used in dose calculations, losses due to food processing (IAEA 1992) and radioactive decay during a human consumption period must be accounted for.

5.2 Integrated Animal Product Concentrations

Animal product concentrations are calculated based on the assumption that they are in equilibrium with the time-variable concentrations in vegetation and soil being consumed by the animal. This is accomplished using published values for the feed-to-animal product *transfer coefficient* which is the fraction of the daily intake of a radionuclide (or element) that is transferred to a particular animal product at equilibrium. For beef, milk, and the optional animal product, four sources of animal feed are evaluated: pasture grass (or range vegetation), stored hay, grain, and legumes. For poultry, only stored grain and legumes are considered as a feed source. Soil ingestion is evaluated for all animal products. Because animal slaughter and milk production occur on a somewhat continuous basis (as opposed to a discrete crop harvest), COMIDA calculates integrated animal product concentrations for consecutive 365-d "accident years" after the date of deposition (Fig. 3).

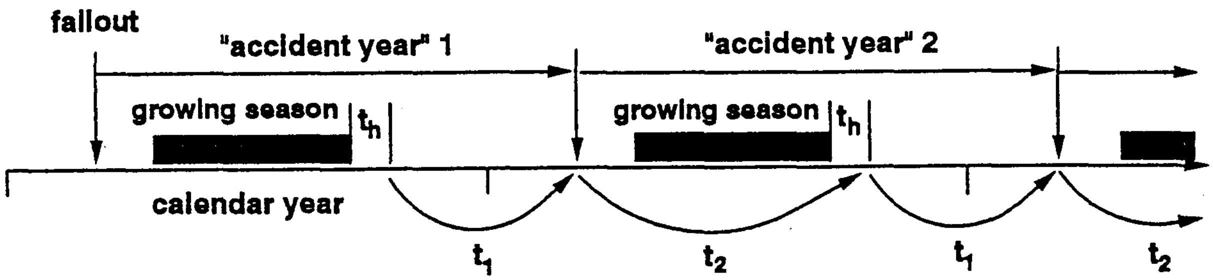

Figure 3. Integrated concentrations for feed crops include contributions from the current year's crop (t_1) and the remaining feed time on the prior year's crop (t_2).

5.2.1 Pasture Grass. A pasture grass or grazing contribution to animal product concentrations is evaluated by integrating current and/or the following year pasture grass inventories only during the portion of the grazing season that occurs in each accident year. If the deposition occurs prior to or after the grazing season, then the total integrated pasture concentration (QTIP, Bq d kg^{-1}) for the calculated accident year includes all of the upcoming grazing season:

$$QTIP = \int_{TSL}^{TEL} QP_c(t)\,dt \tag{16}$$

where

$QP_c(t)$ = time-variable pasture grass concentration for the grazing season that occurs in the current accident year (Bq kg^{-1})

TSL = start of the livestock grazing season (Julian d)

TEL = end of the livestock grazing season (Julian d)

If the deposition occurs during the grazing season, then the 365-d "accident year" pasture integration includes contributions from portions of the current and following year's grazing seasons:

$$QTIP = \int_{TI}^{TEL} QP_c(t)\,dt + \int_{TSL}^{365-TI} QP_n(t)\,dt \tag{17}$$

where

$QP_n(t)$ = time variable pasture grass concentration for the grazing season that occurs in the next accident year (Bq kg^{-1})

TI = date of fallout (Julian d)

The integrated animal product concentration from pasture (or range grazing) for each accident year for decay chain member *j* ($QIAP_j$, in Bq d kg^{-1}) is then calculated by:

$$QIAP_j = RP\ TC_j\ QTIP_j\ e^{-\lambda t_h} \tag{18}$$

where

RP = pasture ingestion rate while animal is on pasture (kg d^{-1})

TC_j = pasture to animal product transfer coefficient (d kg^{-1})

t_h = delay (holdup) time between animal slaughter or milking and human ingestion (d)

Values for animal product transfer coefficients (TC_j) are published in several reviews (Ng et al. 1977; Ng et al. 1979a; Ng et al. 1979b; Ng 1982a; Ng et al. 1982b; Baes et al. 1984).

5.2.2 Stored Feed. The model assumes that animals consume stored feed (hay, grain, legumes) from local area harvests when they are not on pasture and that the animals' diet may be supplemented by stored feed while the animals are on pasture. Each calendar year harvest is assumed to be available for consumption for a 365 d feeding period, after which it is replaced by a new calendar year crop. Since this feeding period is not necessarily synchronized with the calculated accident year interval, COMIDA evaluates both the current calendar year crop (integration time t_1, Fig. 3) and the stored feed remaining from the previous year's harvest (integration time t_2). After each crop harvest, feed concentrations can be delayed for a holdup time (t_h) that simulates the delay between harvest and the start of the animal feeding period. Decay and ingrowth of radioactive progeny are evaluated during both the hold-up time and the 365-d integration period. As an example, the total integrated hay concentration (QTIH, Bq d kg^{-1}) for a specific "accident" year is calculated by (Fig. 3):

$$QTIH = \int_0^{t_1} QH_c(t_h)\,dt + \int_0^{t_2} QH_p(t_h + t_1)\,dt \tag{19}$$

where

$QH_c(t_h)$ = current (and first) year hay crop concentration after holdup time, t_h (Bq kg^{-1})

$QH_p(t_h)$ = prior year hay crop concentration after holdup time, t_h (Bq kg^{-1})

t_1 = integration time for current (and first) year hay crop (d)

t_2 = integration time for prior year hay crop (d)

Up to 3 discrete hay cuttings are evaluated in a single year by transferring individual cut inventories (QCUT[k], in Bq kg^{-1} dry weight) to a storage compartment which is evaluated at the time of the last hay cutting. For parent radionuclides or single member decay chains, each cutting is simply decayed (QCUT(k) x $e^{-\lambda t}$) until the time of the last cutting. To account for decay and ingrowth of progeny radionuclides while the hay is in storage, each hay cutting is evaluated using the general solution to chains of linear first order differential equations (Skrabel et al. 1974). For decay chain member *j*, the concentration in hay cutting *k* is evaluated at the time of the last hay cutting by

$$QCUT_j(k) = \lambda_j \; N_j(t) \qquad \textit{and}$$

$$N_j(t) = \sum_{i=1}^{j} \left[\left(\prod_{m=i}^{j-1} \lambda_m \right) \sum_{m=i}^{j} \left(\frac{N_i^0(k) \, e^{-\lambda_m t_k}}{\prod_{\substack{p=i \\ p \neq m}}^{j} (\lambda_p - \lambda_m)} \right) \right] \tag{20}$$

where

$N^0_i(k)$ = number of atoms of decay chain member j in $QCUT_j(k)$ at harvest

= $QCUT_j(k)/\lambda_j$ (atoms kg^{-1})

t_k = time between harvest of hay cutting k and the last hay cutting (s)

λ = decay chain member decay constants (s^{-1})

Assuming each hay cutting produces the same mass of hay, the average concentration in the storage compartment (QH_j, in Bq kg^{-1}) from "n" total hay cuttings at the time of the last hay cutting is

$$QH_j = \frac{\sum_{k=1}^{n} QCUT_j(k)}{n} \tag{21}$$

The integrated animal product concentration from ingestion of contaminated stored hay for decay chain member j ($QIAH_j$, in Bq d kg^{-1}) is then calculated by

$$QIAH_j = QTIH_j \; RH \; TC_j \; e^{-\lambda t_h} \tag{22}$$

where

RH = annual average hay consumption rate by animal (kg d^{-1})

t_h = delay time between animal slaughter or milking and human ingestion (d)

Integrated animal product concentrations from stored grain and legumes are evaluated in the same manner as eqn. 22 except that single crop inventories at harvest are used. These single crop inventories are calculated using eq. 16 except that the transfer factor from exposed to edible surfaces of crops (TVC) is not considered and the concentrations are not converted to wet weight.

5.2.3 Soil Ingestion. COMIDA calculates integrated animal product concentration via soil ingestion ($QIAS_j$, Bq d kg^{-1}) based on the integrated activity in pasture surface soil for decay chain member *j* ($QIPS_j$, in Bq d kg^{-1}) for each calendar year:

$$QIAS_j = QIPS_j \; RS \; TC_j \; e^{-\lambda t_h} \qquad and \qquad QIPS_j = \frac{\int_0^{365} Qss_j dt}{Pss \; Xs} \tag{23}$$

where

RS = animal soil ingestion rate (kg d^{-1})

Qss_j = time-variable surface soil concentration in pasture (Bq m^{-2})

Pss = surface soil density (kg m^{-3})

Xs = surface soil depth (m)

Recommended soil ingestion rates for dairy cattle are 0.50 kg d^{-1} when cows are on full pasture (summer), 1.00 kg d^{-1} when cows are on half-pasture (spring/fall), and 2.00 kg d^{-1} when cows are not on pasture (winter) (Darwin 1990). Since COMIDA only allows input of one ingestion rate, it is recommended that selection of the value be based on the season in which the initial fallout deposition occurs. Although the model calculates intake from soil over the entire year, the season of initial fallout is the most critical because the surface soil inventory is reduced fairly rapidly by percolation. Soil ingestion rates used in PATHWAY for dairy and beef cows, poultry, and sheep are 0.5, 0.01, and 0.102 kg d^{-1}, respectively.

5.2.4 Total Integrated Animal Product Concentrations. The total integrated concentration ($QIAT_j$) for each of the four animal products (beef, milk, poultry, other animal) and each accident year is calculated by summing the contributions from pasture ($QIAP_j$), stored hay ($QIAH_j$), stored grain ($QIAG_j$), stored legumes ($QIAL_j$), and soil ($QIAS_j$):

$$QIAT_j = QIAP_j + QIAH_j + QIAG_j + QIAL_j + QIAS_j \tag{24}$$

6. MODEL PERFORMANCE

6.1 Benchmark Tests

An evaluation of COMIDA's performance was performed by benchmark tests with published output from the PATHWAY model as reported in Whicker et al. (1990) and four other internationally recognized steady-state models as reported in Hoffman et al. (1984). These models included AIRDOS-EPA (U. S. Environmental Protection Agency), IAEA (International Atomic Energy Agency) Safety Series No. 57, ABG (Allgemeine Berechnungsgrundlage, Federal Republic of Germany), and Regulatory Guide 1.109 (U. S. Nuclear Regulatory Commission).

The four models compared by Hoffman provided concentrations in food products for a unit deposition *rate* from a steady-state release while COMIDA and PATHWAY are based on a unit acute deposition. To compare the two types of results, the acute concentration per unit deposition must be integrated to infinity (Whicker et al. 1990). COMIDA food product concentrations were integrated for 100 years for ^{137}Cs and ^{90}Sr and 1 year for ^{131}I. This accounted for about 90% of the ^{137}Cs and ^{90}Sr radioactivity and 100% of the ^{131}I radioactivity. The geometric mean of the default parameter values used in the steady-state models were used in COMIDA where applicable; otherwise, values from PATHWAY (Whicker and Kirchner 1987) were used. A value of 2.6 $m^2\ kg^{-1}$ was used in COMIDA for the foliar interception constant (α) which corresponds to the geometric mean of the r/Y (interception fraction/yield) values used in the steady-state models. This value is appropriate for deposition of gases and particles smaller than a few microns. A value of 0.39 $m^2\ kg^{-1}$ was used for α in PATHWAY runs to simulate larger fallout particles from weapons tests. Time-integrated concentrations were calculated with COMIDA for deposition events occurring each month of the year. Corresponding output values from PATHWAY were interpolated from graphs reported in Whicker et al. (1990). Since the steady-state model results were obtained using growing season input values (e.g. r/Y values > 0), output from these models are only compared for depositions that occur during the growing season (1 May to 1 September).

Comparisons of ^{131}I and ^{137}Cs integrated milk concentrations from the various models are shown in Fig. 4 and Fig. 5, respectively. Both COMIDA and PATHWAY show a strong seasonal dependence relative to the date of fallout and, in general, exhibit similar curve shapes. During the pasture growing season (March through September), the COMIDA results are very similar to those predicted by the steady-state models while the PATHWAY results are almost an order of magnitude lower. However, the PATHWAY results would have been about 5 times higher and very near to the COMIDA results if the same α value had been used (Whicker et al. 1990). In COMIDA, the largest source of ^{131}I intake and subsequent transfer to milk during the pasture grazing season (10 May through 30 September) was from the consumption of fresh forage by dairy cows. During the late fall and winter months, ^{131}I intake was primarily from soil ingestion. For ^{137}Cs in milk (Fig. 5), the difference between concentrations from accidents that occur during the pasture season and those that occur in the fall and winter months was not as great as in the case of ^{131}I. This is due to the longer ^{137}Cs half-life (30 y) which results in a greater contribution from the root uptake pathway in subsequent years. The spike in the COMIDA ^{137}Cs milk concentration for the August deposition was due to contamination of the third hay crop two weeks prior to harvest. Previous deposition dates occurred much earlier than hay crop harvests, which resulted in more weathering and smaller hay concentrations at harvest.

The time-integrated concentration in leafy vegetables for ^{90}Sr is shown in Fig. 6. No PATHWAY results were available for this comparison. The COMIDA results show a strong seasonal increase for fallout events that occur prior to harvest (31 August), after which, the concentration drops to its pre-growing season value. This increase is due to: 1) the logistical crop growth rate simulated in COMIDA and the resulting increase in the vegetation interception fraction (FV); and 2) and the shorter weathering times for depositions that occur prior to harvest. Direct deposition accounted for about 91% of the total radioactivity transferred to leafy vegetables for the August event.

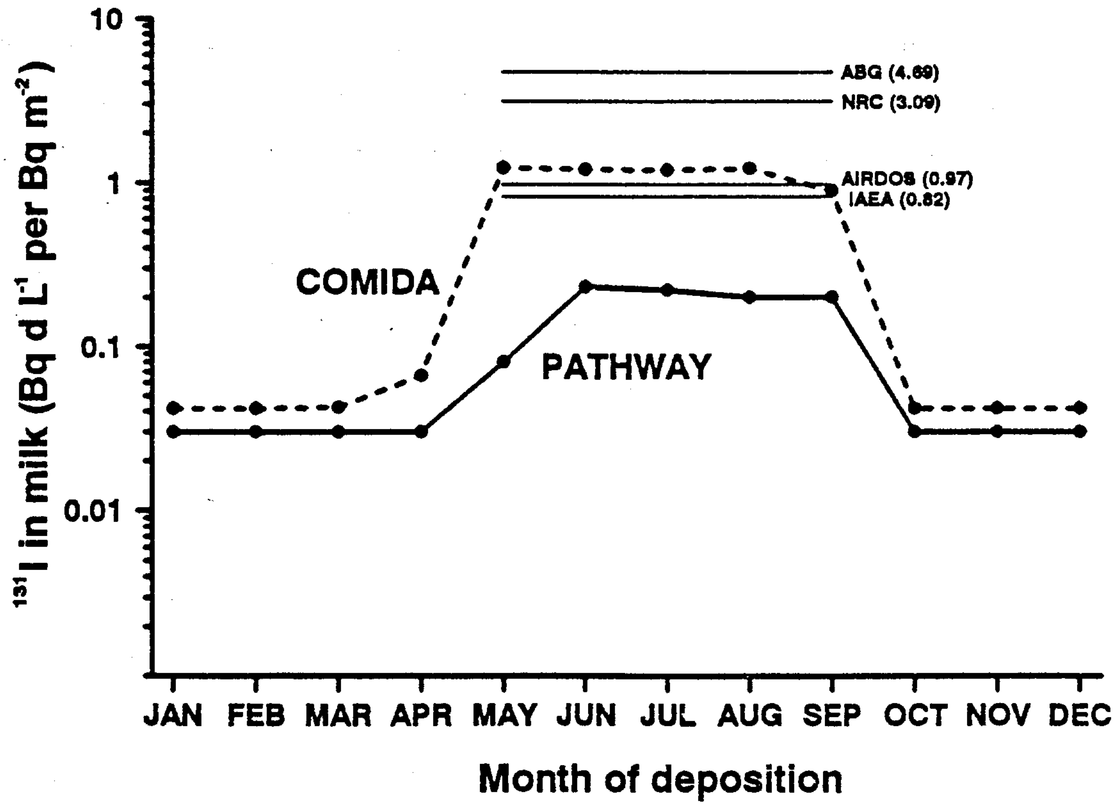

Figure 4. Benchmark results for ^{131}I concentrations in milk.

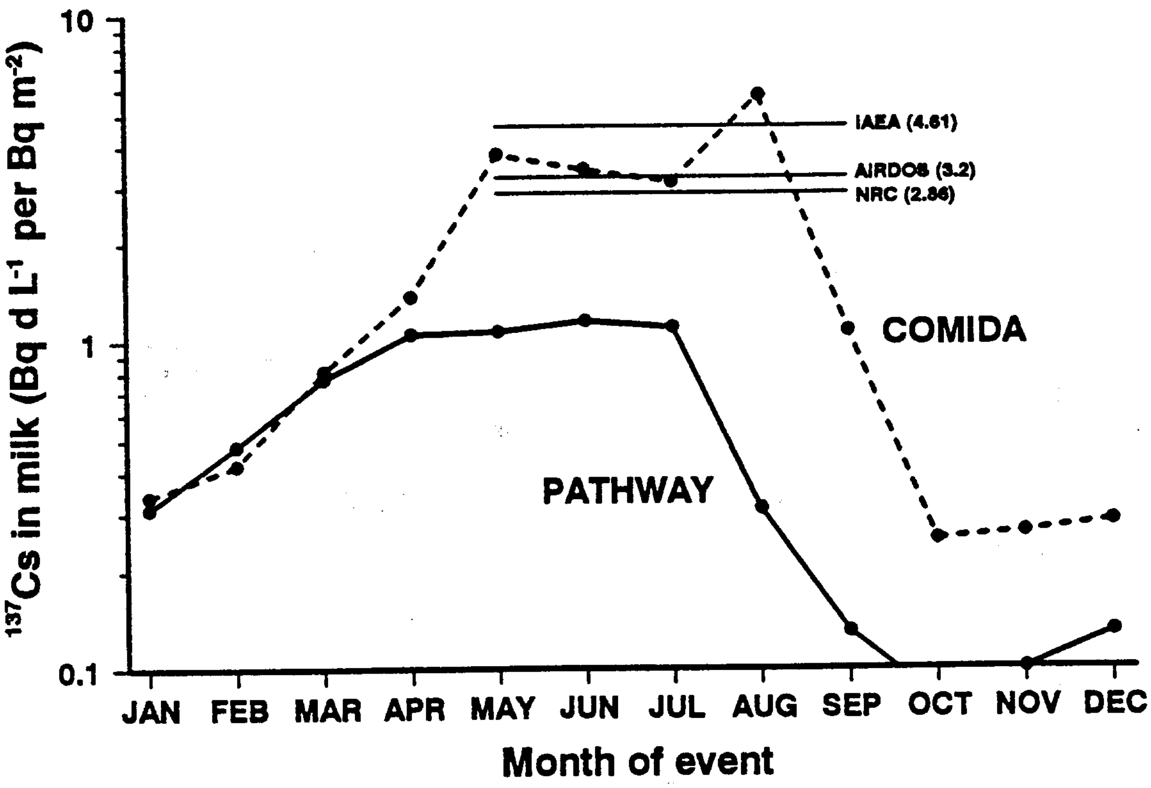

Figure 5. Benchmark results for ^{137}Cs concentrations in milk.

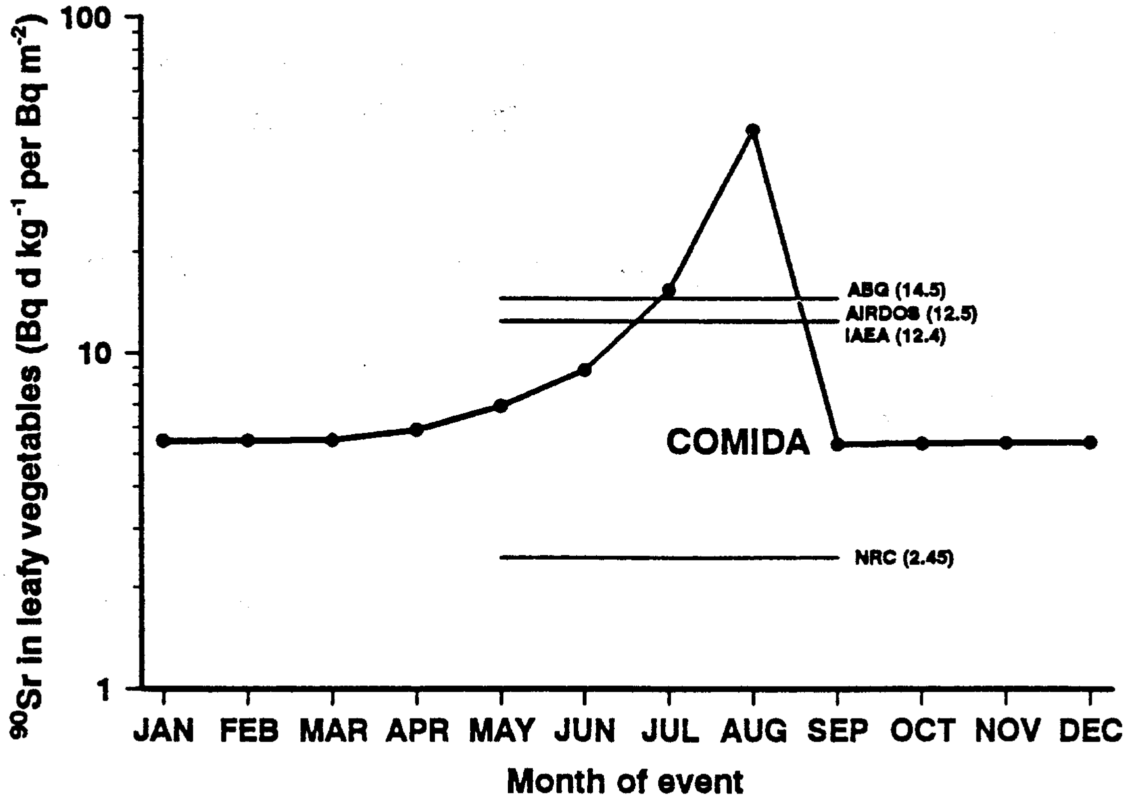

Figure 6. Benchmark results for ^{90}Sr concentrations in leafy vegetables.

In another benchmark test, COMIDA results were compared to 4-year integrated ^{137}Cs beef concentrations predicted by PATHWAY for 13 Nevada Test Site fallout events in southeastern Utah as reported in Whicker and Kirchner (1987) (Fig. 7). About 75% of the 4-year integrated amount calculated by COMIDA was obtained during the first year. The COMIDA results follow the same seasonal trend as those from PATHWAY although COMIDA values are about 50% higher during the middle and latter part of the growing season. For two early season events, COMIDA predicted slightly lower integrated concentrations than PATHWAY.

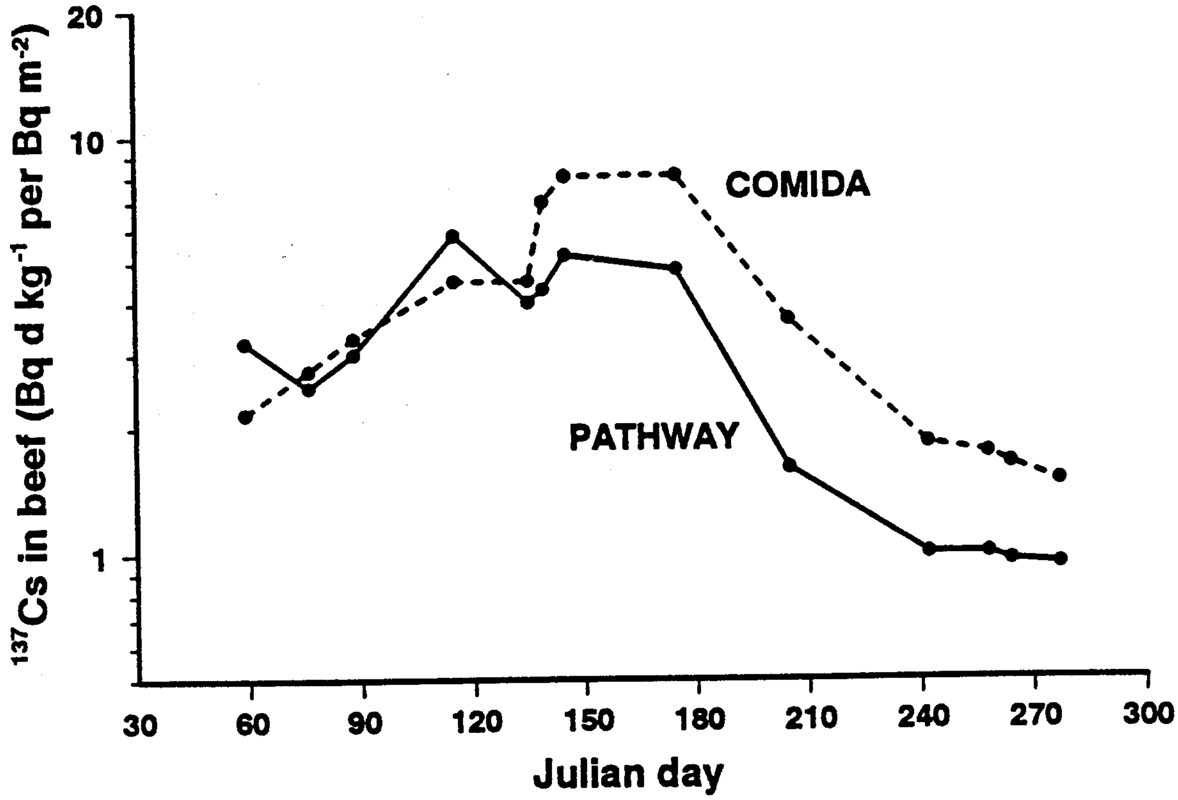

Figure 7. Benchmark results for ^{137}Cs concentrations in beef.

6.2 Differences Between COMIDA and the PATHWAY model

While COMIDA includes many of the processes modeled in PATHWAY and, in general, was designed after PATHWAY, there are several significant differences between the two models:

1) Both models use a logistic plant growth model (Fig. 8) to calculate vegetation interception fractions and root uptake rates. However, PATHWAY adjusts the plant growth rate constant (Kg) at each time step based on daily temperature and light growth rate modifiers while COMIDA does not (constant Kg throughout the growing season). The growth rate modifiers reduce the maximum potential growth rate and result in a longer time over which the plant is actively growing (plant growth rate curve is not as steep). For accidents that occur during the initial period of the growing season, COMIDA may estimate a smaller vegetation biomass and, as a result, smaller initial deposition on vegetation surfaces (Fig. 8). This will result in less radioactivity being fixed into the internal vegetation compartment via foliar absorption. The effects on the vegetation surface compartment for crops is negligible because, for both models, weathering will result in loss of most of the surface activity by the time harvest occurs. The constant Kg used in COMIDA also results in a faster rate of root uptake that slows to an insignificant rate earlier in the growing season. For depositions that occur later in the growing season, COMIDA may predict less root uptake than PATHWAY for the first year because the COMIDA plant growth rate slows to an insignificant rate earlier. However, root uptake is generally an insignificant pathway for first year concentrations when compared to direct foliar deposition.

2) In the benchmark examples, PATHWAY evaluated a livestock diet consisting of fractional intakes of different feed sources by month. In COMIDA, stored feed consumption (hay and grain) is averaged over a 365-d feeding period. Also, COMIDA accounts for up to three hay harvests per year while PATHWAY considered five.

3) In order to account for transfer of radioactivity from plants to surface soil via senescence, PATHWAY evaluates loss of *biomass* in vegetables crops, pasture grass, plants

7. APPLICATION OF RESULTS IN DOSE CALCULATIONS

The food product radioactivity concentrations calculated by COMIDA may be used to estimate human dose due to ingestion. For crops, harvest concentrations must be integrated over a defined human consumption period (typically assumed to be 12 months). For evaluation of a *single member* decay chain, the dose to organ k may be calculated by

$$D_{ik} = GC\left[\int_0^{tc_i} QTC_i\, e^{-\lambda t} dt\right] e^{-\lambda th_i} R_i\, FL_i\, FP_i\, DF_k \qquad (25)$$

where

D_{ik} = dose to organ *k* from consumption of crop *i* (Sv) (dose is acquired over an assumed consumption period, tc)

GC = initial ground concentration of radionuclide (Bq m^{-2})

QTC_i = COMIDA-calculated concentration in crop *i* at harvest (Bq kg^{-1}) per (Bq m^{-2})

R_i = average daily ingestion rate of crop *i* over the consumption period, tc (kg d^{-1})

FL_i = fraction of crop *i* locally produced (unitless)

FP_i = radioactivity fraction remaining in crop *i* after processing (unitless)

DF_k = dose conversion factor for organ k (Sv Bq^{-1})

tc_i = human consumption period over which annual harvest of crop *i* is assumed to be consumed (day)

th_i = holdup (storage) time between harvest of crop *i* and the start of consumption (day)

During the consumption period, it is assumed that human consumption rate is uniform. The daily ingestion rate of the crop (R_i) during this time must therefore be averaged over this consumption period.

In order to evaluate multi-member decay chains, equation (25) becomes

$$D_{ik} = GC\left[\int_0^{tc_i} QTC_i(t_h)\ dt\right] R_i\, FL_i\, FP_i\, DF_k \tag{26}$$

where

$QTC_j(t_h)$ = crop concentration of decay chain member *j* after the holdup period, t_h, which is evaluated by using the general solution to decay chains given in equation (21):

$$QTC_j(t_h) = \lambda_j\ N_j(t_h) \qquad and$$

$$N_j(t_h) = \sum_{i=1}^{j}\left[\left(\prod_{m=i}^{j-1}\lambda_m\right)\sum_{m=i}^{j}\left(\frac{N_i^0(t)\,e^{-\lambda_m t_h}}{\prod_{\substack{p=i\\p\neq m}}^{j}(\lambda_p-\lambda_m)}\right)\right] \tag{27}$$

where

$N_j(t)$ = atom concentration at the end of the holdup period (atoms kg^{-1})

$N^0_i(t)$ = atom concentration of decay chain member *j* at harvest = $QTC_j(t)/\lambda_j$ (atoms kg^{-1})

In order to obtain the integrated concentration for each decay chain member over the consumption period, the integrated form of the above equation must be used:

$$\left[\int_0^{t_c} QTC(t_h)\,dt\right] = U_j(t_c)\ C \qquad and$$

$$U_j(t_c) = \lambda_j \sum_{i=1}^{j}\left[\left(\prod_{m=i}^{j-1}\lambda_m\right)\sum_{m=i}^{j}\left(\frac{N_i^0\left(1-e^{-\lambda_m t_c}\right)}{\lambda_m\prod_{\substack{p=i\\p\neq m}}^{j}(\lambda_p-\lambda_m)}\right)\right] \tag{28}$$

where

$U_j(t_c)$ = total number of transformations over consumption time, t_c (disintegrations kg^{-1})

N_i^0 = $N_j(t_h)$ from previous steps.

C = conversion factor [(Bq s dis^{-1})(1.16×10^{-5} d s^{-1})]

For animal products, the dose is calculated in a similar manner except that the animal product concentrations, including decay chains, are already integrated in COMIDA over a 12-month consumption period.

8. CODE IMPLEMENTATION

COMIDA is written in FORTRAN 77 and implemented on a personal computer with a DOS operating system. The source code, with minor modification, is compatible with most FORTRAN compilers on UNIX operating systems. Input to the code is through two, free format ASCII files. The first file (COMIDA.PAR) contains value for all parameters that are not nuclide or elemental specific. The second file (COMIDA.VAR) contains the values for all parameters that are nuclide specific. Output is written to two ASCII files. The first file (COMIDA.OUT) contains a formatted listing of selected output. The second file (COMIDA.DMP) contains a print out of intermediate calculated values. Data in this file is useful for benchmark purposes and to help in understanding the code. A complete listing of the FORTRAN code is contained in Appendix B.

8.1 Computational Methods

One of the primary tasks of a computer code application to a dynamic food chain model is to perform the numerical integration of the ordinary differential equations (ODE) that mathematically describe the system. This task is accomplished in COMIDA through the implementation of a forth order Runge-Kutta routine with adaptive stepsize control (Press et al., 1986, see subroutine RK4SOLVE). The adaptive stepsize control allows the routine to select the optimum time step to take in order to achieve a predetermined accuracy in the solution and results in a solution of fifth order accuracy. For example, in portions of the solution curve where the slopes are steep, many small steps must be taken in order to achieve the same accuracy as in smooth areas of the curve, where larger steps may be taken. Therefore, this routine is very efficient in terms of providing a solution that is of *consistent* accuracy and only requires an accuracy criteria be selected. Note that the input requirements of COMIDA do not require a time step for the Runge-Kutta solution. The time step is automatically selected based on the hardwired accuracy limit of 1.0E-6, an initial stepsize of 2.5 d and a minimum step size of 1.0E-20 d. A maximum of 50,000 steps are allowed before the routine is terminated.

The stored animal feed compartments (grain, legumes and hay) require calculation of radioactive decay and ingrowth, and integration of the radioactivity during the 12 month ingestion period. Inventories in these compartments are calculated outside of the Runge-Kutta solver using a generalized analytical solution to the sets of ODE's that describe radioactive decay and ingrowth (Equation 27 and 28). This routine was adapted from a BASIC program written and described by Birchall (1987). The routine was translated to FORTRAN and is used to decay, ingrow, and integrate the activity present in the animal feed storage compartments.

8.2 Program Flow

Program flow is controlled by the **MAIN** program unit (Figure 9). Parameter values in the COMIDA.PAR file are read by the **INPUTPAR** subroutine that is called by **MAIN**. Variables that control the number of calendar years results are printed for are also read in the **INPUTPAR** subroutine. First year results are always calculated and written to the output file (COMIDA.OUT). The number of nuclides evaluated and nuclide specific data are read by **MAIN** through the COMIDA.VAR file. First year concentrations, then subsequent year concentrations are calculated for each nuclide. Concentrations for the year the accident occurred are calculated in **CROP1**, **HAY1** and **PASTURE1** subroutines. These subroutines account for the timing of the accident relative to the growing and livestock pasture season and calculate the fallout fractions to vegetation and soil. Concentrations for subsequent years are calculated in the **CROPN**, **HAYN** and **PASTUREN** subroutines. Concentrations in animal products for any year (including the first year) are calculated in the **BEEF**, **MILK**, **POULTRY**, and **OTHER** subroutines. Concentrations in crops and animal products are written to the COMIDA.OUT file after each call to **ONEYEAR** and **NYEAR** subroutines. After concentrations for all nuclides present in the COMIDA.VAR file have been calculated, the program is terminated.

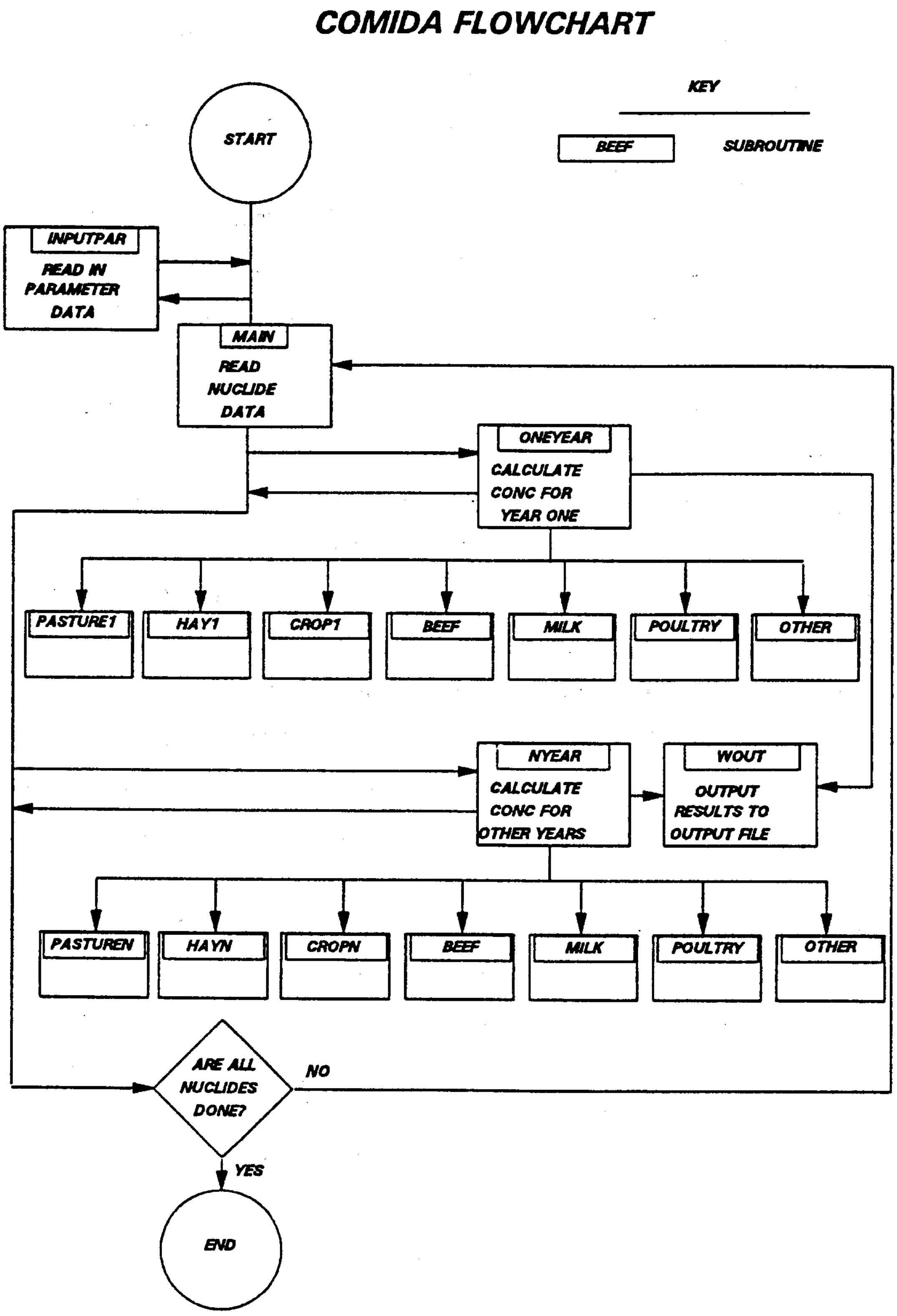

Figure 9. Program flowchart for the COMIDA food-chain model.

8.3 Subroutines

MAIN: This program unit begins and terminates program execution (Figure 9). The routine calls the subroutine **INPUTPAR** (reads parameter input data from the file COMIDA.PAR) and subroutines **ONEYEAR** (food product concentrations the first year) and NYEAR (food product concentrations for all other years). Nuclide specific data is read from this program unit from the file, COMIDA.VAR.

INPUTPAR: This subroutine reads non-nuclide specific data from the COMIDA.PAR file and writes this data to the output file (COMIDA.OUT). Each data record passed to the subroutine **CHECK** for validation. Called by **MAIN**.

CHECK: This subroutine receives a parameter value from the subroutine **INPUTPAR** and assures that the value lies between the maximum and minimum acceptable value (See Table 1.)

TIMECK: This subroutine checks the time variables for conflicts in the start and end dates for growing seasons and pasture grazing season.

ONEYEAR: This subroutine calculates time flag variables that are passed to subroutines **CROP1**, **HAY1**, **PASTURE1**, **BEEF**, **MILK**, **POULTRY**, and **OTHER** for calculation of the first year food product concentrations. The subroutine, **WOUT** is also called for writing output to the file COMIDA.OUT. Decay rate constants (λ) are calculated for each decay chain member and leach rate constants (Kl) are assigned to a common block variable. Called by **MAIN**.

NYEAR: This subroutine calls the subroutines **CROPN**, **HAYN**, **PASTUREN**, **BEEF**, **MILK**, **POULTRY**, and **OTHER** for calculation of food product concentrations for years other than the first. Results are output through a call to the output routine, **WOUT**. Called by **MAIN**.

WOUT: This subroutine writes formatted output of the concentration in food products for each year designated by the variables NTIMES and KYEAR to the file, COMIDA.OUT. Called by **ONEYEAR** and **NYEAR**.

CROP1: This subroutine calculates food product concentrations in crops for the first year (see Figure 10). One of three options may be exercised depending on the timing of the accident relative to the start of the growing season and harvest. The code variable, TYEAR, calculated in the subroutine, **ONEYEAR**, controls these options. The options are 1) accident occurrs during the growing season, 2) accident occurrs before the growing season and, 3) accident occurrs after harvest. Output from this routine includes concentrations at time of harvest for each crop type. The subroutine, **FEEDI**, is called to decay feed inventories for the feed hold up time and integrate the inventories during the consumption period. **FEEDI** is called by **ONEYEAR**.

PASTURE1: This subroutine calculates the first (accident) year integrated pasture inventory (Figure 11). Like the **CROP1** subroutine, one of three options may be exercised depending on the timing of the accident. The integrated pasture inventory for the time during the accident year the cows are on pasture and the accident year integrated soil inventory are output. Also, a short term integrated pasture inventory (user input variable, TINTM) is also output (see subroutine **SHORT**). Called by **ONEYEAR**.

HAY1: This subroutine calculates the first (accident) year hay inventory (Figure 12) and integrates the inventory for the amount of time in the accident year that it is used as feed (Equation 28). Like the **CROP1** subroutine, one of three options may be exercised depending on the timing of the accident. The integrated hay inventory is output. Called by **ONEYEAR**.

BEEF: This subroutine calculates the integrated concentration in beef at the time of consumption for the first and subsequent 365 day periods following an accident. The

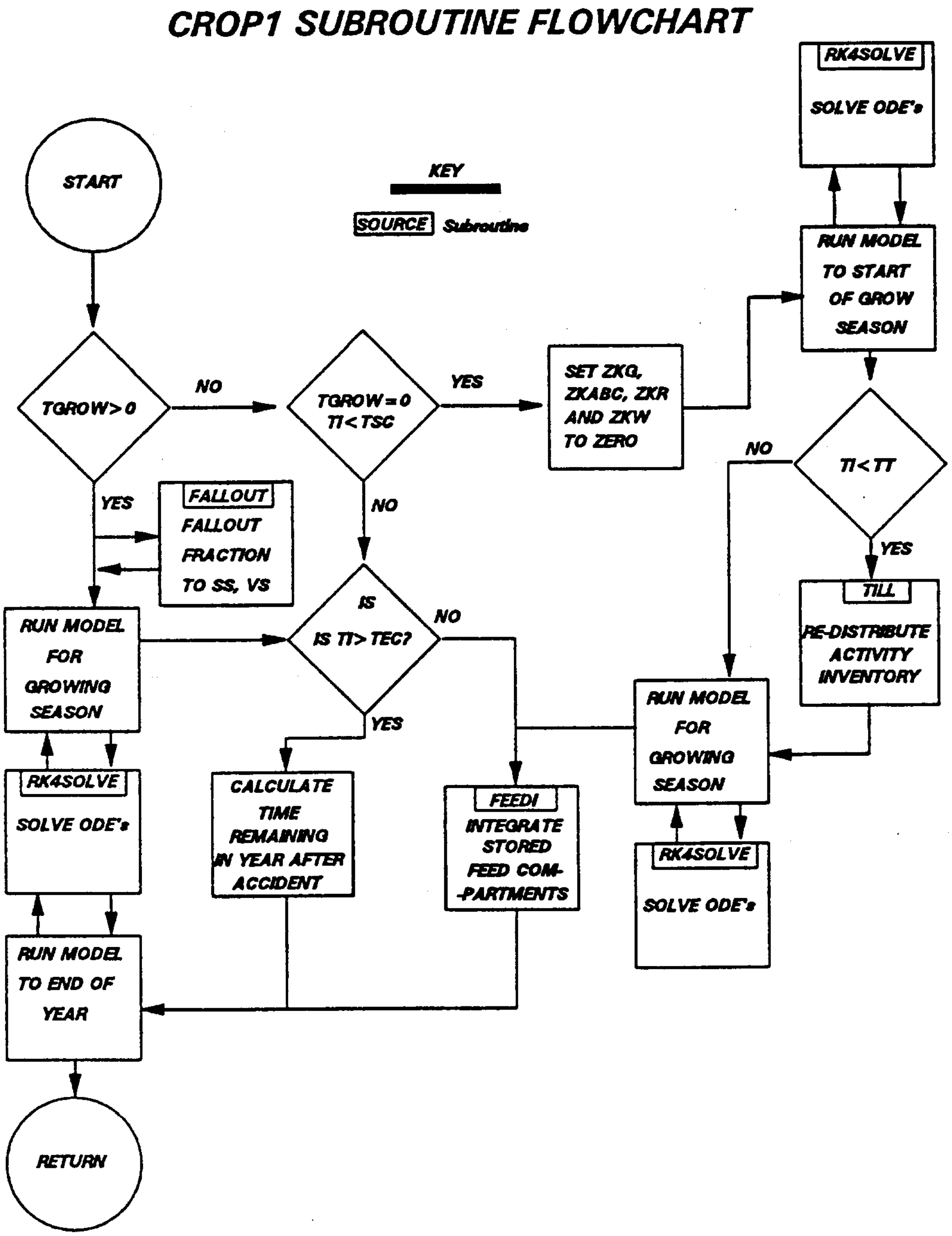

Figure 10. Flowchart of the CROP1 subroutine. Called by ONEYEAR.

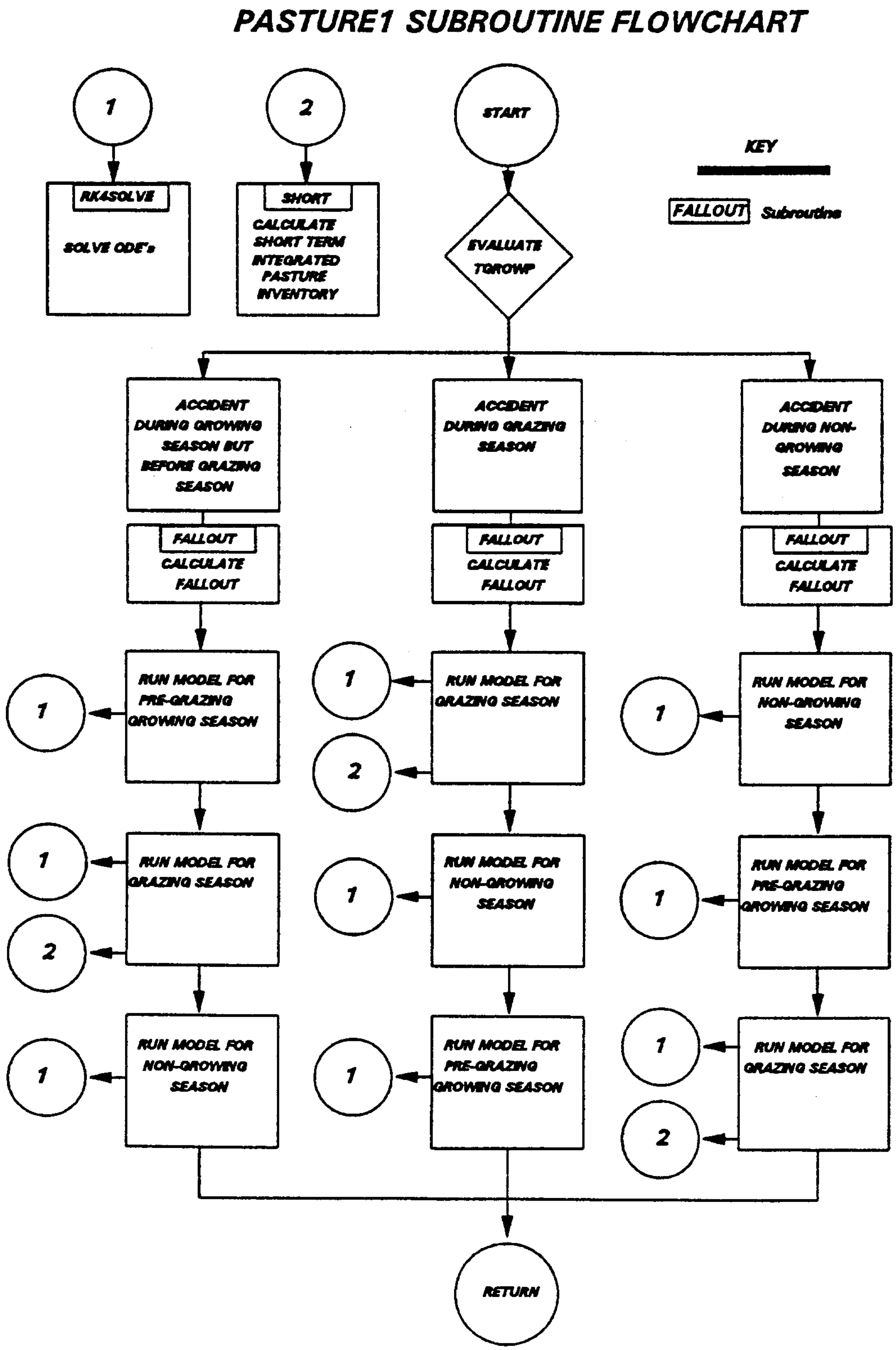

Figure 11. Flowchart for the PASTURE1 subroutine. Called by ONEYEAR.

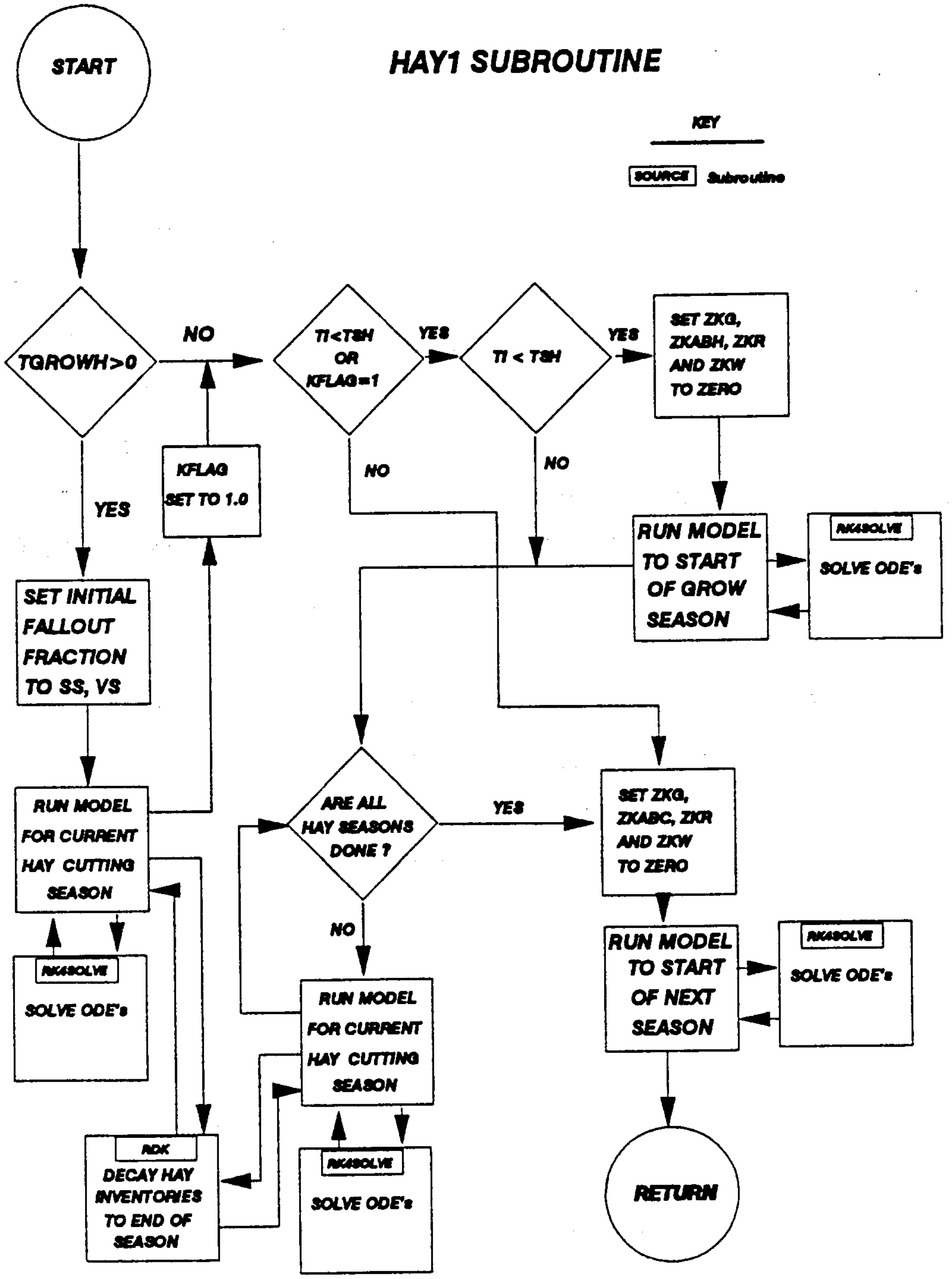

Figure 12. Flowchart for the HAY1 subroutine. Called by ONEYEAR.

integrated beef inventory from pasture, grain, hay, legume and soil is output. Concentration of the parent nuclide in beef is decayed for the holdup time from slaughter to consumption. Progeny are not decayed or ingrown during this time period. Called by **ONEYEAR** and **NYEAR**.

__MILK:__ This subroutine calculates the integrated concentration in milk at the time of consumption for the first and subsequent 365 day periods following an accident. The integrated milk inventory from pasture, grain, hay legume and soil is output. Concentration of the parent nuclide in milk is decayed for the holdup time from production to human consumption. Progeny are not decayed or ingrown during this time period. A short term integrated milk concentration while cows are on pasture is also output. This time period is defined by the code variable, TINTM and is calculated in the subroutine, **SHORT**. Called by **ONEYEAR** and **NYEAR**.

__POULTRY:__ This subroutine calculates the integrated concentration in poultry at the time of consumption for the first and subsequent 365 day periods following an accident. The integrated poultry inventory from grain, legumes, and soil is output. Concentration of the parent nuclide in poultry is decayed for the holdup time from slaughter to consumption. Progeny are not decayed or ingrown during this time period. Called by **ONEYEAR** and **NYEAR**.

__OTHER:__ This subroutine calculates the integrated concentration in the "other" user defined animal at the time of consumption for the first and subsequent 365 day periods following an accident. The integrated animal inventory from pasture, grain hay, legume and soil is output. Concentration of the parent nuclide in the other animal is decayed for the holdup time from slaughter to consumption. Progeny are not decayed or ingrown during this time period. Called by **ONEYEAR** and **NYEAR**.

<u>FEEDI</u>: This subroutine calculates the integrated concentration in grain and legume animal feed and decays these inventories for the hold-up times. The subroutine, **RDK**, is called to perform decay and ingrowth calculations, and to integrate the concentrations. Called by **CROP1** and **CROPN**.

<u>CROPN:</u> This subroutine calculates food product concentrations in crops for years other than the first 365 day period following an accident (Figure 13). Output from this routine includes concentrations at time of harvest for each crop type and integrated stored feed inventories. The subroutine, **FEEDI** is called to decay feed inventories for the feed hold-up time and integrate the inventories during the consumption period. Called by **NYEAR** and **ONEYEAR**.

<u>PASTUREN:</u> This subroutine calculates the integrated pasture inventory for accident years other than the first year following an accident (Figure 14). The integrated pasture inventory for the time the cows are on pasture and the accident year integrated soil inventory is output. Called by **NYEAR**.

<u>HAYN:</u> This subroutine calculates the integrated hay inventory for years other than the first year following an accident (Figure 15). The integrated hay inventory is output. Called by **NYEAR** and **ONEYEAR**.

<u>RK4SOLVE:</u> This subroutine calls the Runge-Kutta solving routine and performs the activity to mass conversions necessary for calculation of radioactive progeny ingrowth. Several subroutines are included in **RK4SOLVE**. The subroutines, **ODIENT**, **RKQC**, and **RK4** are adapted from Press et al (1986). The subroutine **DERIVES** is the user supplied subroutine that defines the set of differential equations to be solved. These equations are given by Equations 1 through 6 (see **DERIVES** description). Called by **CROP1**, **PASTURE1**, **HAY1**, **SHORT**, **CROPN**, **HAYN**, and **PASTUREN**.

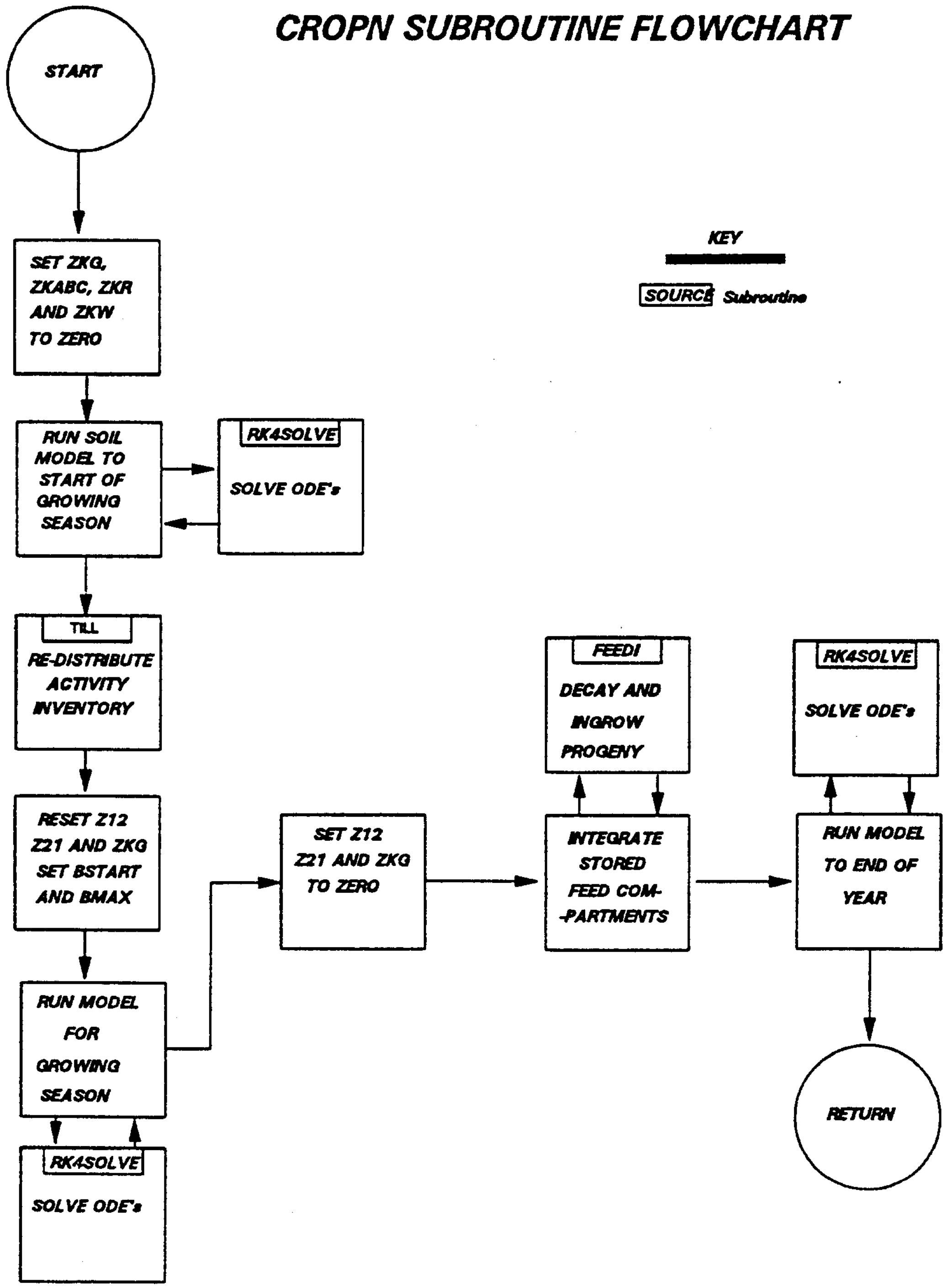

Figure 13. Flowchart for the CROPN subroutine. Called by NYEAR.

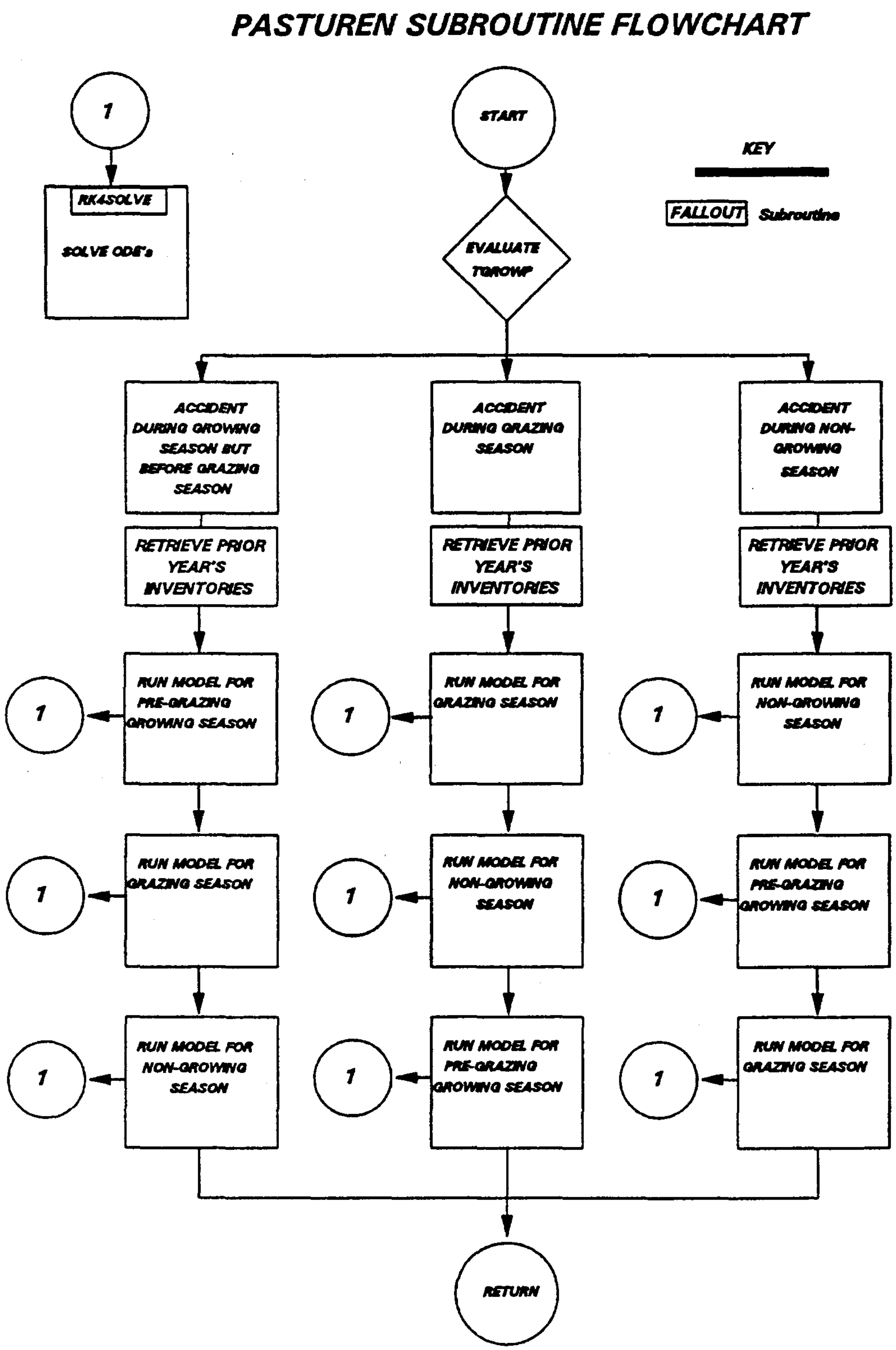

Figure 14. Flowchart for the PASTUREN subroutine.

HAYN SUBROUTINE FLOWCHART

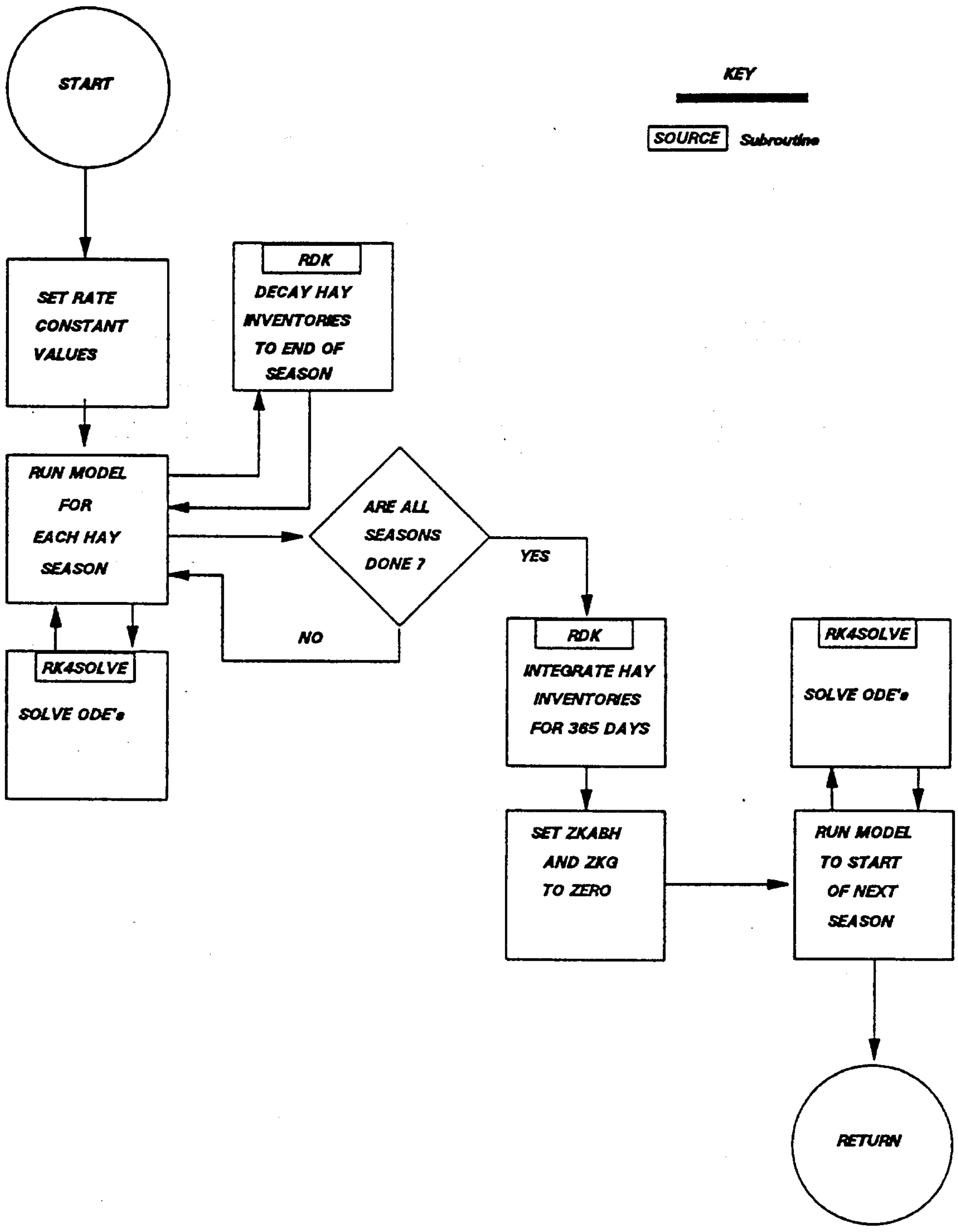

Figure 15. Flowchart for the HAYN subroutine. Called by NYEAR.

<u>TILL:</u> This subroutine calculates the re-distributed soil inventories after tillage (Equation 10). Called by **CROP1** and **CROPN.**

<u>FALLOUT:</u> This subroutine calculates the fallout fraction to vegetation and soil (Equation 13). Called by **CROP1, PASTURE1,** and **HAY1**

<u>SHORT:</u> This subroutine calculates the integrated pasture concentration for a user defined time period (usually shorter than the grazing season) for the year the fallout event occurred on. The amount of time the pasture inventory is integrated over based on the amount of overlap between the time of the accident (TI) plus and the value of TINTM, and the time period when the cows are on pasture. Called by **PASTURE1.**

<u>RDK:</u> This subroutine is used to calculate radioactive decay and ingrowth in stored feed inventories (hay, grain and legumes) (Equation 27). Activity inventories in stored feed and food crops are also integrated (Equation 28) over the consumption period. Several subroutines are included in this **RDK.** These subroutines (**S1000** and **S2000**) have been adapted and translated from the BASIC code presented in Birchall, 1986. Called by **FEEDI, HAY1,** and **HAYN.**

<u>DERIVES:</u> The **DERIVES** subroutine contains the differential equations that define the time variable inventories of each of the state variables (Equations 1 through 6). The time variable compartments are the vegetative surface (Qvs), the soil surface (Qss), the labile soil (Qrs), the vegetative internal (Qvi) and the fixed soil (Qfs). Three additional compartments are used to integrate inventories in the vegetative surface (Qivs), vegetative interior (Qivi) and soil surface (Qiss). The total number of compartments is therefore, eight. This basic model is multiplied by the number of radioactive progeny (four) to make a total of 32 compartments that are solved for each time step (Figure 16). All calculations performed in this subroutine are in units of number of atoms m^{-2}. Activity inventories are converted to number of atoms in the subroutine, **RK4SOLVE.** Each compartment is assigned an array

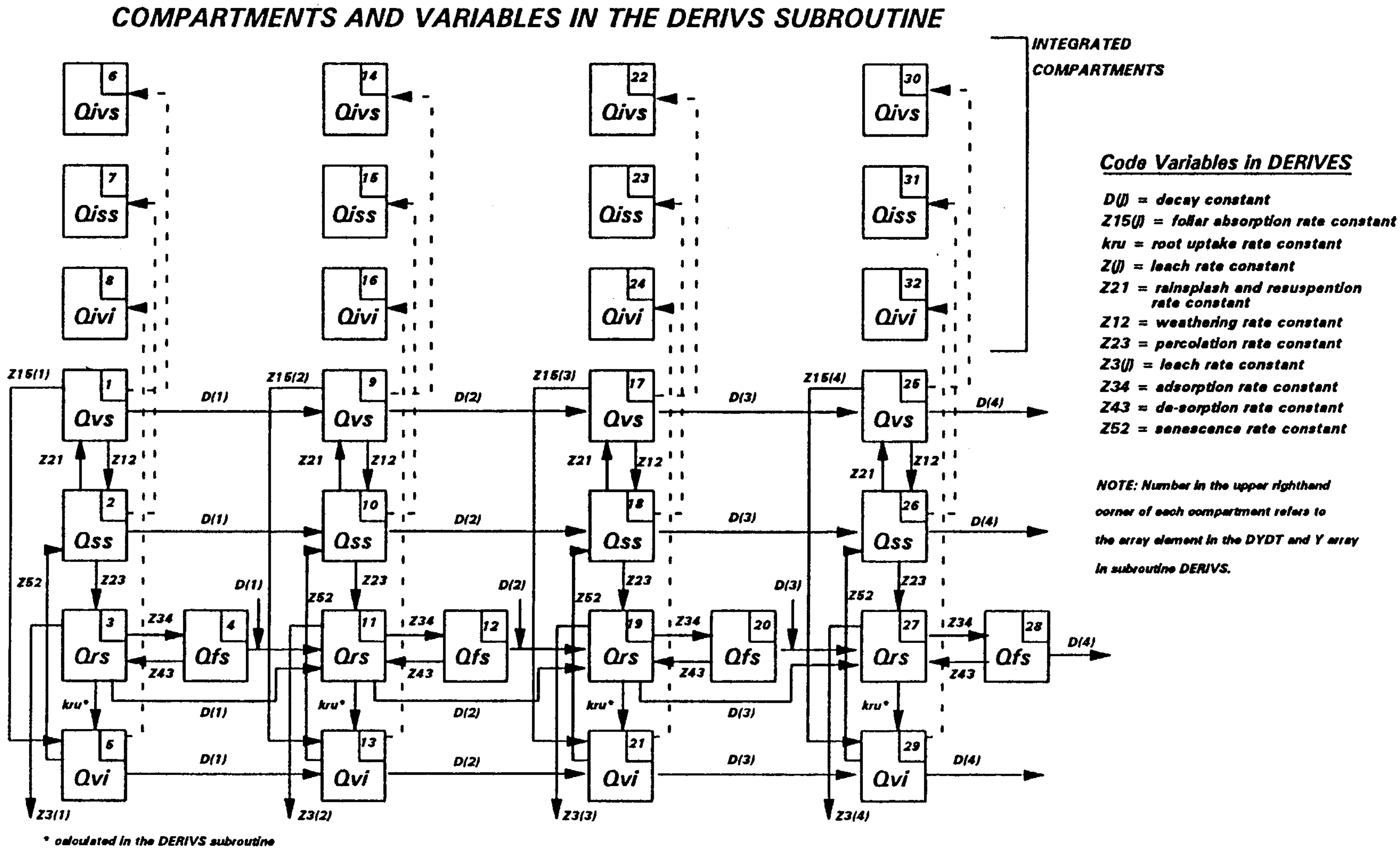

Figure 16. Diagram of the "A" array in the subroutine DERIVS. Note that compartments 9 through 32 are three "mirror images" of compartments 1 through 8.

element (1 to 32). Rate constants are defined in terms of the *parent* compartmental array element they operates on. For example, rate constant "Z21" represents the sum of the rainsplash and resuspension rate constants. The first number in the variable identification (2) designates the "donor" compartment and the last number (1) designates the "receiving" compartment. This designation scheme is followed for each member of the decay chain. Nuclide specific rate constants, decay rate constant (D), leach rate constant (Z3), and foliar absorption rate constant (Z15) are defined as arrays of four elements. Array element 1 refers to the first member of the decay chain (J=1, parent nuclide), array element 2 refers to the second member of the decay chain (J=2, first progeny member), array element 3 refers to the third member of the decay chain (J=3, second progeny member) and array element 4 refers to the forth member of the decay chain (J=4, third progeny member). Called by **ODEINT**, **RKQC**, and **RK4**.

8.4 COMIDA Input Files

Two input files are required for execution of COMIDA. The names of these files have been "hardwired" to COMIDA.PAR and COMIDA.VAR. The COMIDA.PAR file contains accident and scenario specific data and data that is not nuclide specific. The COMIDA.VAR file contains all nuclide specific data. These files are free format and therefore do not require a specific numeric format or column position however, a value for each input variable must be present in the file. Comments may follow the last value read on a line. Line by line input to these files is given in Tables 1 and 2. A further explanation of several of the input parameters follows.

The variable, TINTM, is the number of days from the time of the fallout event, that the transfer of radioactivity from pasture forage and soil, to dairy products (milk) is evaluated for. This computation (calculated in subroutine **SHORT**) calculates the integrated pasture forage and pasture soil concentration while dairy cows are on pasture for the time period, TI (time of fallout event) to TI+TINTM. This value is then passed to subroutine **MILK** to calculate the "Short Term" integrated milk concentration. The calculation is performed separately from the "accident" (first) year pasture forage and milk computations, and may be used to evaluate the benefits of restricting grazing immediately following a fallout event. The amount of time the pasture forage and pasture soil are integrated over depends on the amount of time dairy cows are on pasture from the time of the fallout event, to TINTM days past the event. For example, suppose TI is Julian day 100, TINTM = 60 days, TSL is Julian day 120, and TEL is Julian day 300. Dairy cow consumption of pasture forage and pasture soil is evaluated from Julian day 100 (the day of the accident) to Julian day 160 (TI+TINTM). Since grazing begins on day 120, the integration time for pasture and soil inventories is 160 - 120 = 40 days. This is the amount of time cows are on pasture from the time of the accident to time TI + TINTM. If the accident occurred on day 310, then no "Short Term" integrated milk concentration would be calculated since dairy cows would not be on pasture during the time period, TI to TI+TINTM. Values for the "Short Term" integrated milk concentration from pasture are output for the first accident year only.

The NTIMES variable is the *number* of "accident" years that results are to be printed for. The KYEAR variable is the array that holds the "*accident year numbers*" that results are printed for. The value of, KYEAR(NTIMES), (the last value read by KYEAR) is the number of years from the time of the fallout event, that results are calculated for. For example if NTIMES=6, then results are printed for six separate accident years. The years designated by NTIMES may be consecutive (1, 2, 3, 4 ...) or skip some years where results are not preferred (1, 10, 20 ,30 ...). However the year numbers must be in increasing order. In this example, six KYEAR values must be present, and the first year must be year 1. Suppose impacts out to 50 years from the time of the fallout event is desired with intermediate results also printed. The KYEAR values may be 1, 10, 20, 30, 40 and 50. Given these values for KYEAR and NTIMES, COMIDA will calculate results out to 50 years from the time of the fallout event and print results for year 1, 10, 20 30, 40, and 50.

The NCUTOFF variable is the number of parent half-lives that code will calculate results for before terminating. The variable, CUTOFF, calculated internally, is the number of years from the time of the fallout event that the code will calculate results for before terminating and is given by:

THALF is in days

CUTOFF = NCUTOFF x THALF.

For example, if a nuclide's half life is 3 years and NCUTOF=10 then results will be calculated out to 30 years and zeros will be printed for results beyond 30 years. This variable is used for nuclides with relatively short half-lives when compared to the time period impacts are calculated for. A minimum value of at 10 and a maximum value of 70 is recommended for NCUTOFF. Using a value of 10, only about 0.1% of the original activity remains in the system after this time. Beyond 70 half-lives, the numerical solver in COMIDA becomes somewhat unstable due to rounding error and may result erroneous output.

The animal feed consumption rates used in COMIDA are annual average daily consumption rates for all feeds except pasture. For pasture, the average daily consumption rate of pasture forage, while the animal is on pasture is required. The annual average feed consumption rate is calculated by taking the total amount of a given feed type (grain, legume or hay) consumed in a year and dividing by 365 days. For example if dairy cows consume 2000 kg (dry weight) of hay in a year, then the annual average daily ingestion rate of hay is

$$\frac{2000\ \text{kg}}{365\ \text{d}} = 5.5\ \text{kg d}^{-1}\ \text{(dry weight)}.$$

Pasture forage consumption rates requires, the average daily consumption rate of pasture forage while the animal is on pasture. For example, if a beef cow consumes 800 kg of pasture (dry weight) during the grazing season, and the grazing season lasts 150 days, then the average daily ingestion rate of pasture forage is

$$\frac{800\ \text{kg}}{150\ \text{d}} = 5.33\ \text{kg d}^{-1}\ \text{(dry weight)}.$$

Table 1. Description of COMIDA input parameters for the COMIDA.PAR file. The MIN and MAX values refer to the allowable minimum and allowable maximum values for that variable that the code will accept.

Card	Record	Variable	Code Variable	Type	Description
1	1	—	TITLE	CHARACTER	80 character title of computer simulation.
2	1 to 5	TVC	TVC(I)	REAL	Transfer factor from the exposed to edible surfaces of crops for grains (I=1), leafy vegetables (I=2), root crops (I=3), fruits (I=4), and legumes (I=5). Array of 5 elements. (unitless). MIN:0.0 MAX:1.0
3	1 to 5	Kg	ZKGC(I)	REAL	Crop growth rate constants for grains (I=1), leafy vegetables (I=2), root crops (I=3), fruits (I=4), and legumes (I=5). Array of 5 elements. (d^{-1}). MIN:0.0 MAX:10
4	1 to 5	BI	BIC(I)	REAL	Initial crop biomass for grains (I=1), leafy vegetables (I=2), root crops (I=3), fruits (I=4), and legumes (I=5). Array of 5 elements. (kg m^{-2}, dry weight). MIN:1E-6 MAX:100
5	1 to 5	BMAX	BMAXC(I)	REAL	Maximum crop biomass for grains (I=1), leafy vegetables (I=2), root crops (I=3), fruits (I=4), and legumes (I=5). Array of 5 elements. (kg m^{-2} dry weight). MIN:1E-2 MAX:1000
6	1 to 5	BSTAND	BSTAND(I)	REAL	Maximum standing biomass for grains (I=1), leafy vegetables (I=2), root crops (I=3), fruits (I=4), and legumes (I=5). Array of 5 elements. (kg m^{-2} dry weight). MIN:1E-2 MAX:1000
7	1 to 5	FD	FD(I)	REAL	Ratio of dry to wet weight for grains (I=1), leafy vegetables (I=2), root crops (I=3), fruits (I=4), and legumes (I=5). Array of 5 elements. (unitless). MIN:1E-10 MAX:1.0
8	1	Kg	ZKGP	REAL	Growth rate constant for pasture (d^{-1}). MIN:0 MAX:10
8	2	Ksen	ZSEN	REAL	Senescence rate constant for pasture (d^{-1}). MIN:0 MAX:10
9	1	BI	BIP	REAL	Initial biomass for pasture (kg m^{-2}, dry weight). MIN:1E-6 MAX:100
9	2	BMAX	BMAXP	REAL	Maximum biomass for pasture (kg m^{-2}, dry weight). MIN:1E-2 MAX:1000
10	1	Kg	ZKGH	REAL	Growth rate constant for hay (d^{-1}). MIN:0 MAX:10
10	2	BI	BIH	REAL	Initial biomass for hay (kg m^{-2}, dry weight). MIN:1E-6 MAX:100
10	3	BMAX	BMAXH	REAL	Maximum biomass for hay (kg m^{-2}, dry weight) MIN:1E-2 MAX:1000
11	1	—	NCUT	INTEGER	Number of hay cuttings in a year. MIN:1 MAX:3
11	2	—	TCUT(K)	REAL	Time of K^{th} hay cutting. Array of 3 elements where NCUT number of values are read. (Julian day) MIN:1 MAX:365
12	1	RP	RPB	REAL	Daily consumption rate of pasture for beef cattle while on pasture (kg d^{-1}, dry weight). MIN:0 MAX:100
12	2	RH	RHB	REAL	Annual average consumption rate of hay for beef cattle (kg d^{-1}, dry weight). MIN:0 MAX:100

Table 1. (continued).

Card	Record	Variable	Code Variable	Type	Description
12	3	RG	RGB	REAL	Annual average consumption rate of grain for beef cattle (kg d^{-1}, dry weight). MIN:0 MAX:100
12	3	RS	RSB	REAL	Annual average consumption rate of soil for beef cattle (kg d^{-1}). MIN:0 MAX:100
12	3	RL	RLB	REAL	Annual average consumption rate of legumes for beef cattle (kg d^{-1}, dry weight). MIN:0 MAX:100
13	1	RP	RPM	REAL	Daily consumption rate of pasture for dairy cows while on pasture (kg d^{-1}, dry weight). MIN:0 MAX:100
13	2	RH	RHM	REAL	Annual average consumption rate of hay for dairy cows (kg d^{-1}, dry weight). MIN:0 MAX:100
13	3	RG	RGM	REAL	Annual average consumption rate of grain for dairy cows (kg d^{-1}, dry weight). MIN:0 MAX:100
13	4	RS	RSM	REAL	Annual average consumption rate of soil for dairy cows (kg d^{-1}). MIN:0 MAX:100
13	5	RL	RLM	REAL	Annual average consumption rate of legumes for dairy cows (kg d^{-1}, dry weight). MIN:0 MAX:100
14	1	RG	RGPL	REAL	Annual average consumption rate of grain for poultry (kg d^{-1}, dry weight). MIN:0 MAX:100
14	2	RS	RSPL	REAL	Annual average consumption rate of soil for poultry (kg d^{-1}). MIN:0 MAX:100
14	3	RG	RLPL	REAL	Annual average consumption rate of legumes for poultry (kg d^{-1}, dry weight). MIN:0 MAX:100
15	1	RP	RPO	REAL	Daily consumption rate of pasture for optional other animal while on pasture (kg d^{-1}, dry weight). MIN:0 MAX:100
15	2	RH	RHO	REAL	Annual average consumption rate of hay for optional other animal (kg d^{-1}, dry weight). MIN:0 MAX:100
15	3	RG	RGO	REAL	Annual average consumption rate of grain for optional other animal (kg d^{-1}, dry weight). MIN:0 MAX:100
15	4	RS	RSO	REAL	Annual average consumption rate of soil for optional other animal (kg d^{-1}). MIN:0 MAX:100
15	5	RL	RLO	REAL	Annual average consumption rate of legumes for optional other animal (kg d^{-1}, dry weight). MIN:0 MAX:100
16	1	Kp	ZKP	REAL	Percolation rate constant (d^{-1}). MIN:0 MAX:10
16	2	Kw	ZKW	REAL	Weathering rate constant (d^{-1}). MIN:0 MAX:10
16	3	Kr	ZKR	REAL	Resuspension rate constant (d^{-1}). MIN:0 MAX:10
16	4	Krs	ZKRS	REAL	Rainsplash rate constant (d^{-1}). MIN:0 MAX:10
17	1	Pss	PSS	REAL	Surface soil density (kg m^{-3}). MIN:1 MAX:1E4

Table 1. (continued).

Card	Record	Variable	Code Variable	Type	Description
17	2	ρ_{sr}	PSR	REAL	Labile soil bulk density (kg m^{-3}). MIN:1 MAX:1E4
17	3	Xr	XR	REAL	Thickness of rooting (labile) soil zone (m). MIN:1E-6 MAX:100
17	4	Xs	XS	REAL	Thickness of surface soil (m). MIN:1E-6 MAX:100
18	1 to 7	α	ALPHA(I)	REAL	Foliar interception constant for grains (I=1), leafy vegetables (I=2), root crops (I=3), fruits (I=4), legumes (I=5), hay (I=6) and pasture (I=7). Array, 7 elements (m^2 kg^{-1}). MIN:0 MAX:100
19	1	—	TINTM	REAL	Short term integration time for milk while cows are on pasture (d). MIN:1 MAX:(TEL-TSL)
19	2	TT	TT	REAL	Time of crop tillage (Julian day). MIN:1 MAX:365
19	3	TSC	TSC	REAL	Start of crop growing season (Julian day). MIN:1 MAX:200
19	4	—	TSP	REAL	Start of pasture growing season (Julian day). MIN:1 MAX:200
19	5	TSL	TSL	REAL	Start of livestock grazing season (Julian day). MIN:1 MAX:365
20	1	—	TSH	REAL	Start of hay growing season (Julian day). MIN:1 MAX:200
20	2	TEC	TEC	REAL	Crop harvest time (Julian day). MIN:1 MAX:365
20	3	TEL	TEL	REAL	End of livestock grazing season (Julian day). MIN:1 MAX:365
20	4	TI	TI	REAL	Day of release incident (Julian day) MIN:1 MAX:365
21	1	T_h	THBEEF	REAL	Hold-up time for beef from time of slaughter to time of human ingestion (days). MIN:0 MAX:365
21	2	T_h	THMILK	REAL	Hold-up time for milk from time of production to time of human ingestion (days). MIN:0 MAX:365
21	3	T_h	THPOL	REAL	Hold-up time for poultry from time of slaughter to time of human ingestion (days). MIN:0 MAX:365
21	4	T_h	THOTHER	REAL	Hold-up time for other animal from time of slaughter to time of human ingestion (days). MIN:0 MAX:365
21	5	T_h	THGL	REAL	Hold-up time for grain and legume animal feed from time of harvest to start of consumption (days). MIN:0 MAX:(365-TEC)
21	6	T_h	THHAY	REAL	Hold-up time for hay from time of harvest to start of consumption (days). MIN:0 MAX:(365-TCUT(NCUT))
22	1	—	NTIMES	INTEGER	Number of years results are to be printed for. MIN:1 MAX:100
22	1+NTIMES	—	KYEAR(I)	INTEGER	The year numbers, following the release incident, results are to be printed for. First value of KYEAR must be 1. This corresponds to the year the incident occurred. The last value of KYEAR is the last year results are calculated for. MIN:1 MAX:1E6

Table 2. Description of COMIDA input parameters for the COMIDA.VAR file.

Card	Record	Variable	Code Variable	Type	Description
1	1	—	NNUC	INTEGER	Number of nuclides in simulation
NOTE: Cards 2 through 10 are repeated NNUC number of times					
2	1	—	NUC(1)	CHARACTER	Character array identification for parent nuclide (J=1)
2	2	—	NPROG	INTEGER	Number of progeny (3 maximum)
2	3 to NPROG+3		NUC(J)	CHARACTER	Character array identification for NPROG number of progeny nuclides (J=2 to J=4)
3	1 to 4	—	THALF(J)	REAL	Half life for parent (J=1) and NPROG (J=2 to J=4) number of progeny (d)
4	1 to 4	Kl	ZKL(J)	REAL	Leach rate constant for parent (J=1) and NPROG (J=2 to J=4) number of progeny (d^{-1}).
5	1	Kad	ZKAD	REAL	Adsorption rate constant for parent nuclide in fixed soil (d^{-1}).
5	2	Kde	ZKDE	REAL	Desorption rate constant for parent nuclide in fixed soil (d^{-1}).
5	3	—	NCUTOFF	INTEGER	Number of half-lives to compute concentrations for. (unitless)
NOTE: Cards 6 through 10 are repeated NPROG number of times.					
6	1 to 5	CR	CRC(I,J)	REAL	Concentration ratio for crop I[a] and decay chain member J[a]
7	1 to 5	Kab	ZKABC(I,J)	REAL	Foliar absorption rate constant for crop I[a] and decay chain member J[b] (d^{-1})
8	1	CR	CRP(J)	REAL	Concentration ratio for pasture for decay chain member J[b]
8	2	CR	CRH(J)	REAL	Concentration ratio for hay for decay chain member J[b]
9	1	Kab	ZKABP(J)	REAL	Foliar absorption rate constant for pasture for decay chain member J[b] (d^{-1}).
9	2	Kab	ZKABH(J)	REAL	Foliar absorption rate constant for hay for decay chain member J[b] (d^{-1}).
10	1	TC	TCB(J)	REAL	Beef transfer coefficient for decay chain member J[b] (d kg^{-1})
10	2	TC	TCM(J)	REAL	Milk transfer coefficient for decay chain member J[b] (d L^{-1})
10	3	TC	TCP(J)	REAL	Poultry transfer coefficient for decay chain member J[b] (d kg^{-1})
10	4	TC	TCO(J)	REAL	Other animal transfer coefficient for decay chain member J[b] (d kg^{-1})

(a) The value of I indicates the crop type: 1=grains, 2=leafy vegetables, 3=root crops, 4=fruits, 5=legumes.

(b) The value of J indicates the decay chain member: J=1,the parent, J=2, the first progeny member, J=3, the second progeny member, J=4, the third progeny member.

8.5 COMIDA Output

A formatted printout of output produced by COMIDA is written to the COMIDA.OUT file. The output file contains the following information:

1. Header and version number of code.
2. Accident scenario and site specific data read from the COMIDA.PAR file.
3. Nuclide specific data and results of calculations printed on a nuclide by nuclide basis.
4. Execution time of the code

COMIDA output includes concentrations in crops at the time of harvest and 365 day integrated animal product concentrations for the years selected for printing by the NTIMES and KYEAR variables. Additional values are also reported. These values include concentration in the soil compartments and cumulative integrated crop and animal product inventories.

The concentrations listed under "VEGETATION SURF" and "VEGETATION INT" are the concentrations on the crop surface and in the crop interior at harvest (Bq kg^{-1} wet weight). The surface concentration has been corrected for translocation from the surface to the edible portion of the crop. The "VEGETATION TOTAL" line is the sum of the crop internal and external components. The line "CUMULAT TOT" is sum of the current and all previous accident years harvest concentration. Each individual year's harvest concentration is integrated for 365 d and added to all previous year's integrated harvest concentrations to give an integrated concentration in crops from the time of the accident to the year the results are printed for. The soil concentrations, SURFACE SOIL, LABILE SOIL and FIXED SOIL, are the soil concentrations at the beginning of the next growing season.

The animal feeds, grain, hay, legume, and soil, are integrated for the accident year and include contributions from the current years crops and those from prior years. The grain and legumes concentrations are taken from the human food crop results (calculated in CROP1 and CROPN subroutines). These results are not corrected for surface translocation and are converted to dry weight instead of wet weight. The pasture results represent the integrated concentration during the accident year when animals are on pasture. The "TOTAL" column represents the sum of all five contributions to the integrated animal concentration.

8.6 Sample Problems

Four sample problems are presented in Appendix A for a ^{93}Mo release event that was assumed to occur during each of the four seasons. These examples illustrate the time-dependency of the accident on the food product concentration in addition to the treatment of radioactive progeny in COMIDA. Input values for the parameters used in the sample problems were obtained from Baes and Sharp (1984), Whicker, (1987), and some were assumed. The values used in these examples should not be considered appropriate in for all applications of COMIDA and were used only to demonstrate the code.

The sample problems were run on an IBM Personal System 2, Model 76 486 with a math co-processor. Results were calculated for 15 years past the date of the release event. The execution time for these four cases (fall, winter, spring, summer) was around 60 seconds per case. The same problems were run with a version of COMIDA compiled on a CRAY X-MP/216 and a SUN 4/110 workstation. The CPU run times were 6 seconds for the CRAY X-MP/216 and 56 seconds for the SUN 4/110 workstation.

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APPENDIX A: Sample Problems

Four sample problems are presented in this appendix. These sample problems use a ^{99}Mo source released at four different times of the year: spring, summer, fall and winter. These sample problems demonstrate the radioactive decay and ingrowth features and the seasonal sensitivity of COMIDA. Results were calculated for 15 years past the date of the release event. Results for three of the 15 years are printed to the output file.

```
J=NUMBER OF PROGENY
I=TYPE OF CROP
```

COMIDA.VAR file used for all sample runs.

```
1                                                   NNUC
'MO-93' 1, 'NB-93'                                  NUC(1) NPROG NUC(J..NPROG)
1.277E+06  5.329E+03                                THALF(J)
2.5E-04  1.45E-05                                   ZKL(J)
1.0E-9  1.0E-9  10                                  ZKAD ZKDE ncutoff
0.25   0.25   0.25   0.25   0.25                    CRC(I,J)
5.5E-9 5.5E-9  5.5E-9  5.5E-9  5.5E-9               ZKABC(I,J)
0.20, 0.0016                                        CRP(J) CRH(J)
1.0E-9  1.0E-4                                      ZKABP(J) ZKABH(J)
6.0E-3 1.5E-3, 0.891, 0.912                         TCB(J),TCM(J),TCP(J),TCO(J)
0.01   0.01   0.01   0.01   0.01                    CRC(I,J)
5.5E-9 5.5E-9  5.5E-9  5.5E-9  5.5E-9               ZKABC(I,J)
0.002, 0.0016                                       CRP(J) CRH(J)
.023  1.0E-2                                        ZKABP(J) ZKABH(J)
0.222 0.432, 0.891, 0.912                           TCB(J),TCM(J),TCP(J),TCE(J)
```

COMIDA.PAR input file for release event occurring in fall.

```
'SAMPLE PROBLEM FOR SANDIA NAT LAB USING MO-93 AND NB-93 PROGENY FALL ACCIDENT ' TITLE
0.10  1.00  0.10  0.10   0.10                             TVC(I),I=1,5
0.12  0.12   0.12  0.12  0.12                             ZKGC(I),I=1,5
0.015 0.039   0.039  0.039  0.039                         BIC(I),I=1,5
0.73  0.628  0.628 0.628 0.73                             BMAXC(I),I=1,5
0.73  0.628  0.628 0.628 0.73                             BSTAND(I),I=1,5
0.15  0.27   0.15  0.15  0.15                             FD(I),I=1,5
0.035 0.120                                               ZKGP ZSEN
0.07   0.30                                               BIP BMAXP
0.27 0.08  0.628                                          ZKGH BIH BMAXH
3  170. 230. 290.                                         NCUT (TCUT(I),I=1,NCUT)
8.85 1.7  1.27 0.5  1.2e-1                                RPB RHB RGB RSB RLB
8.85 1.7  1.27 0.5  1.2e-1                                RPM RHM RGM RSM RLM
0.095  0.01  0.01                                         RGPL RLPL RSPL
0.095 0.01 0.01   0.01  0.0                               RPO RHHO RGO RSO RLO
1.98E-2  5.7E-2  1.73E-3  8.6E-4                          ZKP,ZKW,ZKR,Zkrs
1000.0 1400. 0.25  0.001 0.39                             PSS,PSR,XR,XS ALPHA
2.60 2.60 2.60 2.60 2.60 2.60 2.60                        ALPHA(I),I=1,7
71.  65. 75. 110. 111.                                    TINTM TT,TSC,TSP,TSL
120. 290.  300.  285.                                     TSH TEC,TEL,TI
0.,0.,0.,0.,0.,0.                                         THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
3 1 2 15                                                  NTIMES KYEAR
```

COMIDA output file for release event occurring in fall.

```
@(#)main.f       1.4  1/19/93  09:59:00\0
@(#)inputpar.f   1.8  10/25/93  10:24:34\0
TIME: 11:48:57.04
DATE: 10/25/93
TITLE:
SAMPLE PROBLEM FOR SANDIA NAT LAB USING MO-93 AND NB-93 PROGENY FALL ACCIDENT
   ******************** COMIDA *********************
   * A dynamic food chain model for use in the MACCS *
   *          reactor consequence code.              *
   *      Arthur S. Rood and Michael L. Abbott       *
   *     Idaho National Engineering Laboratory       *
   *      EG&G Idaho PO Box 1625 Idaho Falls         *
   *                  ID 83401.                      *
   *            Version Control Copy                 *
   *         Version 1.01  October 25, 1993          *
   ***************************************************
```

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  ===========================================================================
           ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND
                    LIMITATION OF LIABILITY
```

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PARAMETER VALUES FOR COMIDA

------ CROP VALUES ------	GRAINS	LEAFY VEGETABLES	ROOT CROPS	FRUITS	LEGUMES
INTERCEPTION FRAC (m**2/kg):	2.60E+00	2.60E+00	2.60E+00	2.60E+00	2.60E+00
FRACTION TO EDIBLE PORTION OF CROP:	1.00E-01	1.00E+00	1.00E-01	1.00E-01	1.00E-01
GROWTH RATE CONSTANT (d-1):	1.20E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01
INITIAL CROP BIOMASS (kg(dry)/m**2):	1.50E-02	3.90E-02	3.90E-02	3.90E-02	3.90E-02
MAXIMUM CROP BIOMASS (kg(dry)/m**2):	7.30E-01	6.28E-01	6.28E-01	6.28E-01	7.30E-01
STANDING CROP BIOMASS (kg(dry)/m**2):	7.30E-01	6.28E-01	6.28E-01	6.28E-01	7.30E-01
DRY WEIGHT TO WET WEIGHT RATIO:	1.50E-01	2.70E-01	1.50E-01	1.50E-01	1.50E-01

------ ANIMAL FEED PARAMETERS ------	GRAINS	LEGUMES	HAY	PASTURE*	SOIL
GROWTH RATE CONSTANT (d**-1):	---	---	2.70E-01	3.50E-02	---
INITIAL CROP BIOMASS (kg(dry)/m**2):	---	---	8.00E-02	7.00E-02	---
MAXIMUM CROP BIOMASS (kg(dry)/m**2):	---	---	6.28E-01	3.00E-01	---
FOLIAR INTERCEPTION FRAC (m**2/kg):	---	---	2.60E+00	2.60E+00	---
SENESCENCE RATE CONSTANT (d-1):	---	---	---	1.20E-01	---
ANNUAL AVG BEEF COW CONSUMPTION (kg/d):	1.27E+00	1.20E-01	1.70E+00	8.85E+00	5.00E-01
ANNUAL AVG MILK COW CONSUMPTION (kg/d):	1.27E+00	1.20E-01	1.70E+00	8.85E+00	5.00E-01
ANNUAL AVG POULTRY CONSUMPTION (kg/d):	9.50E-02	1.00E-02	---	---	1.00E-02
ANNUAL AVG OTHER ANIMAL CONSUMP (kg/d):	1.00E-02	0.00E+00	1.00E-02	9.50E-02	1.00E-02

* ingestion rate only while animal is on pasture

```
----- OTHER FEED PARAMETERS -----
NUMBER OF HAY CUTTINGS:                          3
HAY CUTTING TIMES (JULIAN DAY):              170. 230. 290.
SHORT TERM PASTURE INT. TIME FOR MILK (d):       7.10E+01
```

```
------ SOIL PARAMETERS ------
PERCOLATION RATE CONSTANT (d**-1):              1.98E-02
WEATHERING RATE CONSTANT (d**-1):               5.70E-02
RESUSPENTION RATE CONSTANT (d**-1):             1.73E-03
RAINSPLASH RATE CONSTANT (d**-1):               8.60E-04
SURFACE SOIL DENSITY (kg/m**3):                 1.00E+03
ROOT SOIL DENSITY (kg/m**3):                    1.40E+03
DEPTH OF ROOTING ZONE (m):                      2.50E-01
SURFACE SOIL COMPARTMENT THICKNESS (m):         1.00E-03

------ TIME PARAMETERS ------
TIME OF TILLAGE (JULIAN DAY):                    65.
START OF CROP GROWING SEASON (JULIAN DAY):       75.
START OF PASTURE GROWING SEASON (JULIAN DAY):   110.
START OF GRAZING SEASON (JULIAN DAY):           111.
START OF HAY GROWING SEASON (JULIAN DAY):       120.
END OF CROP GROWING SEASON (JULIAN DAY):        290.
END OF GRAZING SEASON (JULIAN DAY):             300.
TIME OF FALLOUT EVENT (JULIAN DAY):             285.
HOLD-UP TIME, BEEF (DAYS):                        0.
HOLD-UP TIME, MILK (DAYS):                        0.
HOLD-UP TIME, POULTRY (DAYS):                     0.
HOLD-UP TIME, OTHER ANIMAL (DAYS):                0.
HOLD-UP TIME, ANIMAL FEED GRAIN&LEGUME (DAYS):    0.
HOLD-UP TIME, ANIMAL FEED HAY (DAYS):             0.

UNITS: CROP CONCENTRATION:       Bq/kg (wet weight)
       ANIMAL FEED COMPARTMENTS: Bq/m**2 (dry weight)
       SOIL COMPARTMENTS:        Bq/m**2
       MILK: Bq-d/L
       MEAT: Bq-d/kg
NUMBER OF NUCLIDES EVALUATED   1

PARENT NUCLIDE NAME: MO-93  NUMBER OF PROGENY:  1
SOIL ADSORPTION RATE CONSTANT (d**-1)  1.00E-09
SOIL DESORPTION RATE CONSTANT (d**-1)  1.00E-09
NUMBER OF HALF LIVES TO CUTOFF         10
CUTOFF TIME (years)                    3.50E+04
----------------------------------------------
DATA FOR MEMBER # 1 MO-93  HALF LIFE (d)  1.277E+06  LEACH RATE (d**-1)  2.50E-04
   CROP TYPE >>>        GRAINS   LEAF VEG ROOT     FRUITS   LEGUMES  HAY      PASTURE
CONCENTRATION RATIO     7.00E+01 7.00E+01 7.03E+01 7.03E+01 7.03E+01 1.60E-03 2.00E-01
FOLIAR ABSORPTION       5.50E-09 5.50E-09 5.50E-09 5.50E-09 5.50E-09 1.00E-04 1.00E-09
   ANIMAL PRODUCT >>>   BEEF (d/kg) MILK (d/L)  POUL (d/kg) OTHER (d/kg)
TRANSFER COEFFICIENT    6.00E-03    1.50E-03    8.91E-01    9.12E-01

----------------------------------------------
DATA FOR MEMBER # 2 NB-93  HALF LIFE (d)  5.329E+03  LEACH RATE (d**-1)  1.45E-05
   CROP TYPE >>>        GRAINS   LEAF VEG ROOT     FRUITS   LEGUMES  HAY      PASTURE
CONCENTRATION RATIO     1.00E-02 1.00E-02 1.00E-02 1.00E-02 1.00E-02 1.60E-03 2.00E-03
FOLIAR ABSORPTION       5.50E-09 5.50E-09 5.50E-09 5.50E-09 5.50E-09 1.00E-02 2.30E-02
   ANIMAL PRODUCT >>>   BEEF (d/kg) MILK (d/L)  POUL (d/kg) OTHER (d/kg)
TRANSFER COEFFICIENT    2.22E-01    4.32E-01    8.91E-01    9.12E-01

============== RESULTS FOR ACCIDENT YEAR NUMBER  1=================
RESULTS FOR MEMBER #  1 GRAINS  LEAF VEG   ROOT     FRUITS   LEGUMES

VEGETATION SURF (Bq/kg) 1.32E-02 2.62E-01 1.45E-02 1.45E-02 1.32E-02
SURFACE SOIL (Bq/m**2)  1.71E-02 1.86E-02 1.86E-02 1.86E-02 1.71E-02
LABILE SOIL (Bq/m**2)   3.31E-01 3.63E-01 3.63E-01 3.63E-01 3.31E-01
FIXED SOIL (Bq/m**2)    3.72E-08 4.08E-08 4.08E-08 4.08E-08 3.72E-08
VEGETATION INT (Bq/kg)  4.19E-09 8.30E-09 4.61E-09 4.61E-09 4.19E-09
VEGETATION TOT (Bq/kg)  1.32E-02 2.62E-01 1.45E-02 1.45E-02 1.32E-02
CUMULAT TOT+ (Bq-d/kg)  4.82E+00 9.55E+01 5.30E+00 5.30E+00 4.82E+00
---------------------
```

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	3.17E+02	1.16E+02	3.17E+02	1.95E+01	5.04E+01	---	---
BEEF	2.41E+00	1.19E+00	2.28E-01	1.04E+00	1.51E-01	5.01E+00	5.01E+00
MILK (Bq-d/L)	6.03E-01	2.96E-01	5.70E-02	2.59E-01	3.78E-02	1.25E+00	1.25E+00
POULTRY	2.68E+01	---	2.82E+00	---	4.49E-01	3.01E+01	3.01E+01
OTHER	2.89E+00	1.06E+00	0.00E+00	1.69E+00	4.60E-01	6.10E+00	6.10E+00

----

71. DAY INTEGRATED MILK CONCENTRATION FROM PASTURE (Bq-d/L): 2.53E-01

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	8.58E-06	1.70E-04	9.45E-06	9.45E-06	8.58E-06
SURFACE SOIL (Bq/m**2)	3.41E-04	3.72E-04	3.72E-04	3.72E-04	3.41E-04
LABILE SOIL (Bq/m**2)	6.72E-03	7.36E-03	7.36E-03	7.36E-03	6.72E-03
FIXED SOIL (Bq/m**2)	7.47E-10	8.19E-10	8.19E-10	8.19E-10	7.47E-10
VEGETATION INT (Bq/kg)	2.72E-12	5.39E-12	3.00E-12	3.00E-12	2.72E-12
VEGETATION TOT (Bq/kg)	8.58E-06	1.70E-04	9.45E-06	9.45E-06	8.58E-06
CUMULAT TOT+ (Bq-d/kg)	1.16E-01	2.29E+00	1.27E-01	1.27E-01	1.16E-01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	7.50E+00	2.75E+00	7.50E+00	6.46E-02	4.00E-01	---	---
BEEF	2.11E+00	1.04E+00	2.00E-01	1.27E-01	4.44E-02	3.53E+00	3.53E+00
MILK (Bq-d/L)	4.12E+00	2.02E+00	3.89E-01	2.47E-01	8.64E-02	6.86E+00	6.86E+00
POULTRY	6.35E-01	---	6.68E-02	---	3.56E-03	7.05E-01	7.05E-01
OTHER	6.84E-02	2.51E-02	0.00E+00	5.59E-03	3.65E-03	1.03E-01	1.03E-01

----

71. DAY INTEGRATED MILK CONCENTRATION FROM PASTURE (Bq-d/L): 7.78E+01

============== RESULTS FOR ACCIDENT YEAR NUMBER 2=================

RESULTS FOR MEMBER # 1	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	3.39E-06	7.76E-05	4.31E-06	4.31E-06	3.39E-06
SURFACE SOIL (Bq/m**2)	1.25E-04	1.38E-04	1.38E-04	1.38E-04	1.26E-04
LABILE SOIL (Bq/m**2)	2.87E-01	3.21E-01	3.21E-01	3.21E-01	2.89E-01
FIXED SOIL (Bq/m**2)	1.40E-07	1.56E-07	1.56E-07	1.56E-07	1.41E-07
VEGETATION INT (Bq/kg)	7.33E-03	1.33E-02	7.43E-03	7.43E-03	6.83E-03
VEGETATION TOT (Bq/kg)	7.33E-03	1.34E-02	7.43E-03	7.43E-03	6.84E-03
CUMULAT TOT+ (Bq-d/kg)	7.49E+00	1.00E+02	8.02E+00	8.02E+00	7.31E+00

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	2.21E+01	1.67E+00	2.09E+01	6.73E-02	7.69E-02	---	---
BEEF	1.68E-01	1.70E-02	1.50E-02	3.57E-03	2.31E-04	2.04E-01	5.22E+00
MILK (Bq-d/L)	4.20E-02	4.25E-03	3.76E-03	8.93E-04	5.77E-05	5.10E-02	1.30E+00
POULTRY	1.87E+00	---	1.86E-01	---	6.85E-04	2.05E+00	3.21E+01
OTHER	2.01E-01	1.52E-02	0.00E+00	5.83E-03	7.01E-04	2.23E-01	6.32E+00

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	1.60E-07	3.67E-06	2.04E-07	2.04E-07	1.61E-07
SURFACE SOIL (Bq/m**2)	8.24E-06	9.04E-06	9.04E-06	9.04E-06	8.27E-06
LABILE SOIL (Bq/m**2)	2.07E-02	2.30E-02	2.30E-02	2.30E-02	2.08E-02
FIXED SOIL (Bq/m**2)	9.64E-09	1.06E-08	1.06E-08	1.06E-08	9.66E-09
VEGETATION INT (Bq/kg)	1.71E-04	3.25E-04	1.81E-04	1.81E-04	1.66E-04
VEGETATION TOT (Bq/kg)	1.71E-04	3.28E-04	1.81E-04	1.81E-04	1.66E-04
CUMULAT TOT+ (Bq-d/kg)	2.39E-01	2.52E+00	2.55E-01	2.55E-01	2.33E-01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	1.02E+00	7.94E-02	9.77E-01	3.79E-03	6.17E-03	---	---
BEEF	2.87E-01	3.00E-02	2.60E-02	7.44E-03	6.85E-04	3.51E-01	3.88E+00

MILK (Bq-d/L)	5.58E-01	5.83E-02	5.07E-02	1.45E-02	1.33E-03	6.83E-01	7.54E+00
POULTRY	8.61E-02	---	8.71E-03	---	5.50E-05	9.49E-02	8.00E-01
OTHER	9.28E-03	7.24E-04	0.00E+00	3.28E-04	5.63E-05	1.04E-02	1.13E-01

============== RESULTS FOR ACCIDENT YEAR NUMBER 15================

RESULTS FOR MEMBER # 1	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	2.69E-07	8.42E-06	4.67E-07	4.67E-07	3.01E-07
SURFACE SOIL (Bq/m**2)	9.98E-06	1.49E-05	1.49E-05	1.49E-05	1.12E-05
LABILE SOIL (Bq/m**2)	2.28E-02	3.49E-02	3.48E-02	3.48E-02	2.57E-02
FIXED SOIL (Bq/m**2)	5.81E-07	7.06E-07	7.05E-07	7.05E-07	6.01E-07
VEGETATION INT (Bq/kg)	5.83E-04	1.45E-03	8.04E-04	8.04E-04	6.07E-04
VEGETATION TOT (Bq/kg)	5.83E-04	1.45E-03	8.04E-04	8.04E-04	6.07E-04
CUMULAT TOT+ (Bq-d/kg)	1.89E+01	1.24E+02	2.10E+01	2.10E+01	1.84E+01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	1.43E+00	1.65E-04	1.49E+00	1.91E-02	1.92E-03	---	---
BEEF	1.09E-02	1.68E-06	1.07E-03	1.01E-03	5.77E-06	1.30E-02	5.88E+00
MILK (Bq-d/L)	2.72E-03	4.20E-07	2.68E-04	2.53E-04	1.44E-06	3.24E-03	1.47E+00
POULTRY	1.21E-01	---	1.33E-02	---	1.71E-05	1.34E-01	3.93E+01
OTHER	1.30E-02	1.50E-06	0.00E+00	1.65E-03	1.75E-05	1.47E-02	7.06E+00

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	4.88E-07	1.26E-05	7.00E-07	7.00E-07	5.11E-07
SURFACE SOIL (Bq/m**2)	1.79E-05	2.22E-05	2.22E-05	2.22E-05	1.88E-05
LABILE SOIL (Bq/m**2)	4.93E-02	6.10E-02	6.10E-02	6.10E-02	5.16E-02
FIXED SOIL (Bq/m**2)	3.82E-07	4.54E-07	4.53E-07	4.53E-07	3.93E-07
VEGETATION INT (Bq/kg)	1.38E-05	3.55E-05	1.98E-05	1.98E-05	1.49E-05
VEGETATION TOT (Bq/kg)	1.42E-05	4.81E-05	2.05E-05	2.05E-05	1.54E-05
CUMULAT TOT+ (Bq-d/kg)	7.70E-01	3.68E+00	8.70E-01	8.70E-01	7.58E-01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	7.78E-02	1.42E-04	8.24E-02	3.43E-04	6.49E-05	---	---
BEEF	2.19E-02	5.36E-05	2.20E-03	6.73E-04	7.20E-06	2.49E-02	5.03E+00
MILK (Bq-d/L)	4.27E-02	1.04E-04	4.27E-03	1.31E-03	1.40E-05	4.84E-02	9.78E+00
POULTRY	6.59E-03	---	7.34E-04	---	5.78E-07	7.32E-03	1.15E+00
OTHER	7.10E-04	1.30E-06	0.00E+00	2.97E-05	5.92E-07	7.42E-04	1.47E-01

\+ Cumulative 365 day integrated concentration in food products from the time of the accident.

++ Animal feed inventories are corrected for hold-up time from time of harvest to animal consumption time. Animal product concentrations are corrected for decay of the parent nuclide from production (slaughter) to human consumption.

EXECUTION TIME (seconds) 59

COMIDA.PAR input file for release event occurring in winter.

```
'SAMPLE PROBLEM FOR SANDIA NAT LAB USING MO-93 AND NB-93 PROGENY WINTER ACCIDENT ' TITLE
0.10  1.00  0.10  0.10   0.10                          TVC(I),I=1,5
0.12  0.12   0.12  0.12  0.12                          ZKGC(I),I=1,5
0.015 0.039   0.039  0.039  0.039                      BIC(I),I=1,5
0.73  0.628  0.628 0.628 0.73                          BMAXC(I),I=1,5
0.73  0.628  0.628 0.628 0.73                          BSTAND(I),I=1,5
0.15  0.27   0.15  0.15  0.15                          FD(I),I=1,5
0.035 0.120                                            ZKGP ZSEN
0.07   0.30                                            BIP BMAXP
0.27 0.08  0.628                                       ZKGH BIH BMAXH
3  170. 230. 290.                                      NCUT (TCUT(I),I=1,NCUT)
8.85 1.7  1.27 0.5  1.2e-1                             RPB RHB RGB RSB RLB
8.85 1.7  1.27 0.5  1.2e-1                             RPM RHM RGM RSM RLM
0.095  0.01  0.01                                      RGPL RLPL RSPL
0.095 0.01 0.01   0.01  0.0                            RPO RHHO RGO RSO RLO
1.98E-2  5.7E-2  1.73E-3  8.6E-4                       ZKP,ZKW,ZKR,Zkrs
1000.0 1400. 0.25  0.001 0.39                          PSS,PSR,XR,XS ALPHA
2.60 2.60 2.60 2.60 2.60 2.60 2.60                     ALPHA(I),I=1,7
71.  65. 75. 110. 111.                                 TINTM TT,TSC,TSP,TSL
120. 290.  300.  30.                                   TSH TEC,TEL,TI
0.,0.,0.,0.,0.,0.                                      THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
3 1 2 15                                               NTIMES KYEAR
```

COMIDA output file for release event occurring in winter.

```
@(#)main.f       1.4  1/19/93  09:59:00\0
@(#)inputpar.f  1.8  10/25/93  10:24:34\0
TIME: 11:50:00.87
DATE: 10/25/93
TITLE:
SAMPLE PROBLEM FOR SANDIA NAT LAB USING MO-93 AND NB-93 PROGENY WINTER ACCIDENT
   ******************** COMIDA **********************
   * A dynamic food chain model for use in the MACCS *
   *           reactor consequence code.             *
   *      Arthur S. Rood and Michael L. Abbott       *
   *     Idaho National Engineering Laboratory       *
   *      EG&G Idaho PO Box 1625 Idaho Falls         *
   *                  ID 83401.                      *
   *             Version Control Copy                *
   *         Version 1.01  October 25, 1993          *
   ***************************************************
  ==========================================================================
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  ==========================================================================
```

PARAMETER VALUES FOR COMIDA

------ CROP VALUES ------

	GRAINS	LEAFY VEGETABLES	ROOT CROPS	FRUITS	LEGUMES
INTERCEPTION FRAC (m**2/kg):	2.60E+00	2.60E+00	2.60E+00	2.60E+00	2.60E+00
FRACTION TO EDIBLE PORTION OF CROP:	1.00E-01	1.00E+00	1.00E-01	1.00E-01	1.00E-01
GROWTH RATE CONSTANT (d-1):	1.20E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01
INITIAL CROP BIOMASS (kg(dry)/m**2):	1.50E-02	3.90E-02	3.90E-02	3.90E-02	3.90E-02
MAXIMUM CROP BIOMASS (kg(dry)/m**2):	7.30E-01	6.28E-01	6.28E-01	6.28E-01	7.30E-01
STANDING CROP BIOMASS (kg(dry)/m**2):	7.30E-01	6.28E-01	6.28E-01	6.28E-01	7.30E-01
DRY WEIGHT TO WET WEIGHT RATIO:	1.50E-01	2.70E-01	1.50E-01	1.50E-01	1.50E-01

------ ANIMAL FEED PARAMETERS ------	GRAINS	LEGUMES	HAY	PASTURE*	SOIL
GROWTH RATE CONSTANT (d**-1):	---	---	2.70E-01	3.50E-02	---
INITIAL CROP BIOMASS (kg(dry)/m**2):	---	---	8.00E-02	7.00E-02	---
MAXIMUM CROP BIOMASS (kg(dry)/m**2):	---	---	6.28E-01	3.00E-01	---
FOLIAR INTERCEPTION FRAC (m**2/kg):	---	---	2.60E+00	2.60E+00	---
SENESCENCE RATE CONSTANT (d-1):	---	---	---	1.20E-01	---
ANNUAL AVG BEEF COW CONSUMPTION (kg/d):	1.27E+00	1.20E-01	1.70E+00	8.85E+00	5.00E-01
ANNUAL AVG MILK COW CONSUMPTION (kg/d):	1.27E+00	1.20E-01	1.70E+00	8.85E+00	5.00E-01
ANNUAL AVG POULTRY CONSUMPTION (kg/d):	9.50E-02	1.00E-02	---	---	1.00E-02
ANNUAL AVG OTHER ANIMAL CONSUMP (kg/d):	1.00E-02	0.00E+00	1.00E-02	9.50E-02	1.00E-02

* ingestion rate only while animal is on pasture

----- OTHER FEED PARAMETERS -----

NUMBER OF HAY CUTTINGS:	3
HAY CUTTING TIMES (JULIAN DAY):	170. 230. 290.
SHORT TERM PASTURE INT. TIME FOR MILK (d):	7.10E+01

------ SOIL PARAMETERS ------

PERCOLATION RATE CONSTANT (d**-1):	1.98E-02
WEATHERING RATE CONSTANT (d**-1):	5.70E-02
RESUSPENTION RATE CONSTANT (d**-1):	1.73E-03
RAINSPLASH RATE CONSTANT (d**-1):	8.60E-04
SURFACE SOIL DENSITY (kg/m**3):	1.00E+03
ROOT SOIL DENSITY (kg/m**3):	1.40E+03
DEPTH OF ROOTING ZONE (m):	2.50E-01
SURFACE SOIL COMPARTMENT THICKNESS (m):	1.00E-03

------ TIME PARAMETERS ------

TIME OF TILLAGE (JULIAN DAY):	65.
START OF CROP GROWING SEASON (JULIAN DAY):	75.
START OF PASTURE GROWING SEASON (JULIAN DAY):	110.
START OF GRAZING SEASON (JULIAN DAY):	111.
START OF HAY GROWING SEASON (JULIAN DAY):	120.
END OF CROP GROWING SEASON (JULIAN DAY):	290.
END OF GRAZING SEASON (JULIAN DAY):	300.
TIME OF FALLOUT EVENT (JULIAN DAY):	30.
HOLD-UP TIME, BEEF (DAYS):	0.
HOLD-UP TIME, MILK (DAYS):	0.
HOLD-UP TIME, POULTRY (DAYS):	0.
HOLD-UP TIME, OTHER ANIMAL (DAYS):	0.
HOLD-UP TIME, ANIMAL FEED GRAIN&LEGUME (DAYS):	0.
HOLD-UP TIME, ANIMAL FEED HAY (DAYS):	0.

UNITS: CROP CONCENTRATION: Bq/kg (wet weight)
ANIMAL FEED COMPARTMENTS: Bq/m**2 (dry weight)
SOIL COMPARTMENTS: Bq/m**2
MILK: Bq-d/L
MEAT: Bq-d/kg

NUMBER OF NUCLIDES EVALUATED 1

PARENT NUCLIDE NAME: MO-93 NUMBER OF PROGENY: 1

```
SOIL ADSORPTION RATE CONSTANT (d**-1)  1.00E-09
SOIL DESORPTION RATE CONSTANT (d**-1)  1.00E-09
NUMBER OF HALF LIVES TO CUTOFF         10
CUTOFF TIME (years)                    3.50E+04
-----------------------------------------------
DATA FOR MEMBER # 1 MO-93  HALF LIFE (d)  1.277E+06  LEACH RATE (d**-1)  2.50E-04
   CROP TYPE >>>         GRAINS   LEAF VEG ROOT     FRUITS   LEGUMES  HAY      PASTURE
CONCENTRATION RATIO      7.00E+01 7.00E+01 7.03E+01 7.03E+01 7.03E+01 1.60E-03 2.00E-01
FOLIAR ABSORPTION        5.50E-09 5.50E-09 5.50E-09 5.50E-09 5.50E-09 1.00E-04 1.00E-09
   ANIMAL PRODUCT >>>    BEEF (d/kg) MILK (d/L)  POUL (d/kg) OTHER (d/kg)
TRANSFER COEFFICIENT     6.00E-03    1.50E-03    8.91E-01    9.12E-01
                                                   1.9E-1 ? (see page 6-29 of NUREG/CR-5512
-----------------------------------------------
DATA FOR MEMBER # 2 NB-93  HALF LIFE (d)  5.329E+03  LEACH RATE (d**-1)  1.45E-05
   CROP TYPE >>>         GRAINS   LEAF VEG ROOT     FRUITS   LEGUMES  HAY      PASTURE
CONCENTRATION RATIO      1.00E-02 1.00E-02 1.00E-02 1.00E-02 1.00E-02 1.60E-03 2.00E-03
FOLIAR ABSORPTION        5.50E-09 5.50E-09 5.50E-09 5.50E-09 5.50E-09 1.00E-02 2.30E-02
   ANIMAL PRODUCT >>>    BEEF (d/kg) MILK (d/L)  POUL (d/kg) OTHER (d/kg)
TRANSFER COEFFICIENT     2.22E-01    4.32E-01    8.91E-01    9.12E-01

============== RESULTS FOR ACCIDENT YEAR NUMBER  1=================
RESULTS FOR MEMBER #  1 GRAINS  LEAF VEG   ROOT     FRUITS   LEGUMES

VEGETATION SURF (Bq/kg) 9.68E-06 2.03E-04 1.13E-05 1.13E-05 9.69E-06
SURFACE SOIL (Bq/m**2)  3.59E-04 3.59E-04 3.59E-04 3.59E-04 3.59E-04
LABILE SOIL (Bq/m**2)   8.20E-01 8.39E-01 8.39E-01 8.39E-01 8.26E-01
FIXED SOIL (Bq/m**2)    3.10E-07 3.16E-07 3.16E-07 3.16E-07 3.12E-07
VEGETATION INT (Bq/kg)  2.09E-02 7.86E-02 6.31E-02 8.25E-02 9.05E-02
VEGETATION TOT (Bq/kg)  2.10E-02 7.88E-02 6.31E-02 8.25E-02 9.05E-02
CUMULAT TOT+ (Bq-d/kg)  7.65E+00 2.88E+01 2.30E+01 3.01E+01 3.30E+01
----------------------
INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)
                  GRAIN     HAY      LEGUME    PASTURE  SOIL     TOTAL    CUMULATIVE

ANIMAL FEED       1.47E+01 3.80E-01 6.34E+01 5.65E+00 5.04E+01  ---       ---
BEEF              1.12E-01 3.88E-03 4.56E-02 3.00E-01 1.51E-01 6.13E-01 6.13E-01
MILK (Bq-d/L)     2.81E-02 9.70E-04 1.14E-02 7.51E-02 3.78E-02 1.53E-01 1.53E-01
POULTRY           1.25E+00  ---     5.65E-01  ---     4.49E-01 2.26E+00 2.26E+00
OTHER             1.34E-01 3.47E-03 0.00E+00 4.90E-01 4.60E-01 1.09E+00 1.09E+00
----------------------
 71. DAY INTEGRATED MILK CONCENTRATION FROM PASTURE (Bq-d/L):  0.00E+00
RESULTS FOR MEMBER #  2 GRAINS  LEAF VEG   ROOT     FRUITS   LEGUMES

VEGETATION SURF (Bq/kg) 3.21E-07 6.74E-06 3.74E-07 3.74E-07 3.22E-07
SURFACE SOIL (Bq/m**2)  1.86E-05 1.87E-05 1.87E-05 1.87E-05 1.87E-05
LABILE SOIL (Bq/m**2)   4.56E-02 4.64E-02 4.64E-02 4.64E-02 4.58E-02
FIXED SOIL (Bq/m**2)    1.67E-08 1.69E-08 1.69E-08 1.69E-08 1.67E-08
VEGETATION INT (Bq/kg)  4.89E-04 3.05E-03 3.33E-03 5.45E-03 6.99E-03
VEGETATION TOT (Bq/kg)  4.89E-04 3.06E-03 3.33E-03 5.45E-03 6.99E-03
CUMULAT TOT+ (Bq-d/kg)  3.53E-01 1.76E+00 1.72E+00 2.65E+00 3.26E+00
----------------------
INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)
                  GRAIN     HAY      LEGUME    PASTURE  SOIL     TOTAL    CUMULATIVE

ANIMAL FEED       4.42E-01 1.80E-02 5.29E+00 1.75E-01 3.58E-01  ---       ---
BEEF              1.25E-01 6.80E-03 1.41E-01 3.43E-01 3.98E-02 6.55E-01 6.55E-01
MILK (Bq-d/L)     2.42E-01 1.32E-02 2.74E-01 6.68E-01 7.74E-02 1.28E+00 1.28E+00
POULTRY           3.74E-02  ---     4.71E-02  ---     3.19E-03 8.77E-02 8.77E-02
OTHER             4.03E-03 1.64E-04 0.00E+00 1.51E-02 3.27E-03 2.26E-02 2.26E-02
----------------------
 71. DAY INTEGRATED MILK CONCENTRATION FROM PASTURE (Bq-d/L):  2.27E+01
============== RESULTS FOR ACCIDENT YEAR NUMBER  2=================
RESULTS FOR MEMBER #  1 GRAINS  LEAF VEG   ROOT     FRUITS   LEGUMES

VEGETATION SURF (Bq/kg) 7.96E-06 1.71E-04 9.50E-06 9.50E-06 8.05E-06
```

SURFACE SOIL (Bq/m**2)	2.95E-04	3.03E-04	3.03E-04	3.03E-04	2.98E-04
LABILE SOIL (Bq/m**2)	6.75E-01	7.08E-01	7.07E-01	7.07E-01	6.86E-01
FIXED SOIL (Bq/m**2)	5.52E-07	5.70E-07	5.69E-07	5.69E-07	5.58E-07
VEGETATION INT (Bq/kg)	1.72E-02	2.93E-02	1.64E-02	1.64E-02	1.62E-02
VEGETATION TOT (Bq/kg)	1.72E-02	2.95E-02	1.64E-02	1.64E-02	1.62E-02
CUMULAT TOT+ (Bq-d/kg)	1.39E+01	3.95E+01	2.90E+01	3.61E+01	3.89E+01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	4.86E+01	9.42E-01	1.68E+02	6.99E-02	6.65E-02	---	---
BEEF	3.70E-01	9.61E-03	1.21E-01	3.71E-03	2.00E-04	5.05E-01	1.12E+00
MILK (Bq-d/L)	9.26E-02	2.40E-03	3.03E-02	9.28E-04	4.99E-05	1.26E-01	2.80E-01
POULTRY	4.11E+00	---	1.50E+00	---	5.93E-04	5.61E+00	7.88E+00
OTHER	4.43E-01	8.59E-03	0.00E+00	6.06E-03	6.07E-04	4.58E-01	1.55E+00

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	6.51E-07	1.39E-05	7.73E-07	7.73E-07	6.56E-07
SURFACE SOIL (Bq/m**2)	2.94E-05	3.00E-05	3.00E-05	3.00E-05	2.96E-05
LABILE SOIL (Bq/m**2)	7.62E-02	7.85E-02	7.84E-02	7.84E-02	7.69E-02
FIXED SOIL (Bq/m**2)	5.67E-08	5.80E-08	5.79E-08	5.79E-08	5.70E-08
VEGETATION INT (Bq/kg)	4.02E-04	7.15E-04	3.99E-04	3.99E-04	3.93E-04
VEGETATION TOT (Bq/kg)	4.03E-04	7.29E-04	3.99E-04	3.99E-04	3.94E-04
CUMULAT TOT+ (Bq-d/kg)	6.44E-01	2.27E+00	2.01E+00	2.93E+00	3.54E+00

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	2.29E+00	6.57E-02	1.68E+01	1.78E-03	5.04E-03	---	---
BEEF	6.46E-01	2.48E-02	4.48E-01	3.49E-03	5.59E-04	1.12E+00	1.78E+00
MILK (Bq-d/L)	1.26E+00	4.82E-02	8.72E-01	6.80E-03	1.09E-03	2.18E+00	3.46E+00
POULTRY	1.94E-01	---	1.50E-01	---	4.49E-05	3.44E-01	4.31E-01
OTHER	2.09E-02	5.99E-04	0.00E+00	1.54E-04	4.59E-05	2.17E-02	4.43E-02

============== RESULTS FOR ACCIDENT YEAR NUMBER 15==================

RESULTS FOR MEMBER # 1	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	6.33E-07	1.85E-05	1.03E-06	1.03E-06	7.15E-07
SURFACE SOIL (Bq/m**2)	2.35E-05	3.28E-05	3.28E-05	3.28E-05	2.65E-05
LABILE SOIL (Bq/m**2)	5.36E-02	7.68E-02	7.65E-02	7.65E-02	6.09E-02
FIXED SOIL (Bq/m**2)	1.59E-06	1.78E-06	1.78E-06	1.78E-06	1.65E-06
VEGETATION INT (Bq/kg)	1.37E-03	3.18E-03	1.77E-03	1.77E-03	1.44E-03
VEGETATION TOT (Bq/kg)	1.37E-03	3.20E-03	1.77E-03	1.77E-03	1.44E-03
CUMULAT TOT+ (Bq-d/kg)	4.09E+01	9.11E+01	5.75E+01	6.46E+01	6.53E+01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	3.86E+00	4.19E-04	4.03E+00	1.94E-02	1.83E-03	---	---
BEEF	2.94E-02	4.27E-06	2.90E-03	1.03E-03	5.50E-06	3.34E-02	2.87E+00
MILK (Bq-d/L)	7.36E-03	1.07E-06	7.26E-04	2.57E-04	1.38E-06	8.35E-03	7.18E-01
POULTRY	3.27E-01	---	3.59E-02	---	1.63E-05	3.63E-01	2.73E+01
OTHER	3.52E-02	3.82E-06	0.00E+00	1.68E-03	1.67E-05	3.69E-02	3.48E+00

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	1.29E-06	3.07E-05	1.71E-06	1.71E-06	1.35E-06
SURFACE SOIL (Bq/m**2)	4.72E-05	5.40E-05	5.40E-05	5.40E-05	4.96E-05
LABILE SOIL (Bq/m**2)	1.30E-01	1.48E-01	1.48E-01	1.48E-01	1.36E-01
FIXED SOIL (Bq/m**2)	1.08E-06	1.19E-06	1.19E-06	1.19E-06	1.12E-06
VEGETATION INT (Bq/kg)	3.24E-05	7.83E-05	4.35E-05	4.35E-05	3.53E-05
VEGETATION TOT (Bq/kg)	3.37E-05	1.09E-04	4.52E-05	4.52E-05	3.66E-05
CUMULAT TOT+ (Bq-d/kg)	1.89E+00	4.84E+00	3.36E+00	4.28E+00	4.79E+00

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	2.14E-01	3.61E-04	2.26E-01	3.44E-04	6.30E-05	---	---
BEEF	6.02E-02	1.36E-04	6.03E-03	6.76E-04	6.99E-06	6.70E-02	4.93E+00
MILK (Bq-d/L)	1.17E-01	2.65E-04	1.17E-02	1.32E-03	1.36E-05	1.30E-01	9.58E+00
POULTRY	1.81E-02	---	2.02E-03	---	5.61E-07	2.01E-02	1.38E+00
OTHER	1.95E-03	3.30E-06	0.00E+00	2.98E-05	5.74E-07	1.98E-03	1.38E-01

+ Cumulative 365 day integrated concentration in food products from the time of the accident.
++ Animal feed inventories are corrected for hold-up time from time of harvest to animal consumption time. Animal product concentrations are corrected for decay of the parent nuclide from production (slaughter) to human consumption.

EXECUTION TIME (seconds) 58

COMIDA.PAR input file for release event occurring in spring.

```
'SAMPLE PROBLEM FOR SANDIA NAT LAB USING MO-93 AND NB-93 PROGENY SPRING ACCIDENT ' TITLE
0.10  1.00  0.10  0.10   0.10                         TVC(I),I=1,5
0.12  0.12   0.12  0.12  0.12                         ZKGC(I),I=1,5
0.015 0.039   0.039  0.039  0.039  0.039              BIC(I),I=1,5
0.73  0.628  0.628 0.628 0.73                         BMAXC(I),I=1,5
0.73  0.628  0.628 0.628 0.73                         BSTAND(I),I=1,5
0.15  0.27   0.15  0.15  0.15                         FD(I),I=1,5
0.035 0.120                                           ZKGP ZSEN
0.07   0.30                                           BIP BMAXP
0.27 0.08  0.628                                      ZKGH BIH BMAXH
3  170. 230. 290.                                     NCUT (TCUT(I),I=1,NCUT)
8.85 1.7  1.27 0.5  1.2e-1                            RPB RHB RGB RSB RLB
8.85 1.7  1.27 0.5  1.2e-1                            RPM RHM RGM RSM RLM
0.095  0.01  0.01                                     RGPL RLPL RSPL
0.095 0.01 0.01   0.01  0.0                           RPO RHHO RGO RSO RLO
1.98E-2  5.7E-2  1.73E-3  8.6E-4                      ZKP,ZKW,ZKR,Zkrs
1000.0 1400. 0.25  0.001 0.39                         PSS,PSR,XR,XS ALPHA
2.60 2.60 2.60 2.60 2.60 2.60 2.60                    ALPHA(I),I=1,7
71.  65. 75. 110. 111.                                TINTM TT,TSC,TSP,TSL
120. 290.  300.  120.                                 TSH TEC,TEL,TI
0.,0.,0.,0.,0.,0.                                     THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
3 1 2 15                                              NTIMES KYEAR
```

COMIDA output file for release event occurring in spring.

```
@(#)main.f      1.4  1/19/93  09:59:00\0
@(#)inputpar.f  1.8  10/25/93  10:24:34\0
TIME: 11:51:03.54
DATE: 10/25/93
TITLE:
SAMPLE PROBLEM FOR SANDIA NAT LAB USING MO-93 AND NB-93 PROGENY SPRING ACCIDENT
   ******************** COMIDA **********************
   * A dynamic food chain model for use in the MACCS *
   *          reactor consequence code.              *
   *      Arthur S. Rood and Michael L. Abbott       *
   *     Idaho National Engineering Laboratory       *
   *      EG&G Idaho PO Box 1625 Idaho Falls         *
   *                 ID 83401.                       *
   *             Version Control Copy                *
   *          Version 1.01  October 25, 1993         *
   ***************************************************
  ==========================================================================
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             Contract Number DE-AC07-76ID01570.
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  Recipes, Cambridge University Press.
  ==========================================================================
```

PARAMETER VALUES FOR COMIDA

------ CROP VALUES ------

	GRAINS	LEAFY VEGETABLES	ROOT CROPS	FRUITS	LEGUMES
INTERCEPTION FRAC (m**2/kg):	2.60E+00	2.60E+00	2.60E+00	2.60E+00	2.60E+00
FRACTION TO EDIBLE PORTION OF CROP:	1.00E-01	1.00E+00	1.00E-01	1.00E-01	1.00E-01
GROWTH RATE CONSTANT (d-1):	1.20E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01
INITIAL CROP BIOMASS (kg(dry)/m**2):	1.50E-02	3.90E-02	3.90E-02	3.90E-02	3.90E-02
MAXIMUM CROP BIOMASS (kg(dry)/m**2):	7.30E-01	6.28E-01	6.28E-01	6.28E-01	7.30E-01
STANDING CROP BIOMASS (kg(dry)/m**2):	7.30E-01	6.28E-01	6.28E-01	6.28E-01	7.30E-01
DRY WEIGHT TO WET WEIGHT RATIO:	1.50E-01	2.70E-01	1.50E-01	1.50E-01	1.50E-01

------ ANIMAL FEED PARAMETERS ------	GRAINS	LEGUMES	HAY	PASTURE*	SOIL
GROWTH RATE CONSTANT (d**-1):	---	---	2.70E-01	3.50E-02	---
INITIAL CROP BIOMASS (kg(dry)/m**2):	---	---	8.00E-02	7.00E-02	---
MAXIMUM CROP BIOMASS (kg(dry)/m**2):	---	---	6.28E-01	3.00E-01	---
FOLIAR INTERCEPTION FRAC (m**2/kg):	---	---	2.60E+00	2.60E+00	---
SENESCENCE RATE CONSTANT (d-1):	---	---	---	1.20E-01	---
ANNUAL AVG BEEF COW CONSUMPTION (kg/d):	1.27E+00	1.20E-01	1.70E+00	8.85E+00	5.00E-01
ANNUAL AVG MILK COW CONSUMPTION (kg/d):	1.27E+00	1.20E-01	1.70E+00	8.85E+00	5.00E-01
ANNUAL AVG POULTRY CONSUMPTION (kg/d):	9.50E-02	1.00E-02	---	---	1.00E-02
ANNUAL AVG OTHER ANIMAL CONSUMP (kg/d):	1.00E-02	0.00E+00	1.00E-02	9.50E-02	1.00E-02

* ingestion rate only while animal is on pasture

----- OTHER FEED PARAMETERS -----

NUMBER OF HAY CUTTINGS:	3
HAY CUTTING TIMES (JULIAN DAY):	170. 230. 290.
SHORT TERM PASTURE INT. TIME FOR MILK (d):	7.10E+01

------ SOIL PARAMETERS ------

PERCOLATION RATE CONSTANT (d**-1):	1.98E-02
WEATHERING RATE CONSTANT (d**-1):	5.70E-02
RESUSPENTION RATE CONSTANT (d**-1):	1.73E-03
RAINSPLASH RATE CONSTANT (d**-1):	8.60E-04
SURFACE SOIL DENSITY (kg/m**3):	1.00E+03
ROOT SOIL DENSITY (kg/m**3):	1.40E+03
DEPTH OF ROOTING ZONE (m):	2.50E-01
SURFACE SOIL COMPARTMENT THICKNESS (m):	1.00E-03

------ TIME PARAMETERS ------

TIME OF TILLAGE (JULIAN DAY):	65.
START OF CROP GROWING SEASON (JULIAN DAY):	75.
START OF PASTURE GROWING SEASON (JULIAN DAY):	110.
START OF GRAZING SEASON (JULIAN DAY):	111.
START OF HAY GROWING SEASON (JULIAN DAY):	120.
END OF CROP GROWING SEASON (JULIAN DAY):	290.
END OF GRAZING SEASON (JULIAN DAY):	300.
TIME OF FALLOUT EVENT (JULIAN DAY):	120.
HOLD-UP TIME, BEEF (DAYS):	0.
HOLD-UP TIME, MILK (DAYS):	0.
HOLD-UP TIME, POULTRY (DAYS):	0.
HOLD-UP TIME, OTHER ANIMAL (DAYS):	0.
HOLD-UP TIME, ANIMAL FEED GRAIN&LEGUME (DAYS):	0.
HOLD-UP TIME, ANIMAL FEED HAY (DAYS):	0.

UNITS: CROP CONCENTRATION: Bq/kg (wet weight)
ANIMAL FEED COMPARTMENTS: Bq/m**2 (dry weight)
SOIL COMPARTMENTS: Bq/m**2
MILK: Bq-d/L
MEAT: Bq-d/kg

NUMBER OF NUCLIDES EVALUATED 1

PARENT NUCLIDE NAME: MO-93 NUMBER OF PROGENY: 1

SOIL ADSORPTION RATE CONSTANT (d**-1)	1.00E-09
SOIL DESORPTION RATE CONSTANT (d**-1)	1.00E-09
NUMBER OF HALF LIVES TO CUTOFF	10
CUTOFF TIME (years)	3.50E+04

DATA FOR MEMBER # 1 MO-93 HALF LIFE (d) 1.277E+06 LEACH RATE (d**-1) 2.50E-04

CROP TYPE >>>	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES	HAY	PASTURE
CONCENTRATION RATIO	7.00E+01	7.00E+01	7.03E+01	7.03E+01	7.03E+01	1.60E-03	2.00E-01
FOLIAR ABSORPTION	5.50E-09	5.50E-09	5.50E-09	5.50E-09	5.50E-09	1.00E-04	1.00E-09

ANIMAL PRODUCT >>>	BEEF (d/kg)	MILK (d/L)	POUL (d/kg)	OTHER (d/kg)
TRANSFER COEFFICIENT	6.00E-03	1.50E-03	8.91E-01	9.12E-01

DATA FOR MEMBER # 2 NB-93 HALF LIFE (d) 5.329E+03 LEACH RATE (d**-1) 1.45E-05

CROP TYPE >>>	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES	HAY	PASTURE
CONCENTRATION RATIO	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.60E-03	2.00E-03
FOLIAR ABSORPTION	5.50E-09	5.50E-09	5.50E-09	5.50E-09	5.50E-09	1.00E-02	2.30E-02

ANIMAL PRODUCT >>>	BEEF (d/kg)	MILK (d/L)	POUL (d/kg)	OTHER (d/kg)
TRANSFER COEFFICIENT	2.22E-01	4.32E-01	8.91E-01	9.12E-01

============== RESULTS FOR ACCIDENT YEAR NUMBER 1==================

RESULTS FOR MEMBER # 1	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	7.47E-05	1.56E-03	8.66E-05	8.66E-05	7.57E-05
SURFACE SOIL (Bq/m**2)	2.75E-03	2.74E-03	2.74E-03	2.74E-03	2.78E-03
LABILE SOIL (Bq/m**2)	9.30E-01	9.32E-01	9.32E-01	9.32E-01	9.32E-01
FIXED SOIL (Bq/m**2)	2.45E-07	2.45E-07	2.45E-07	2.45E-07	2.44E-07
VEGETATION INT (Bq/kg)	3.83E-04	2.34E-04	1.31E-04	1.31E-04	1.43E-04
VEGETATION TOT (Bq/kg)	4.57E-04	1.79E-03	2.17E-04	2.17E-04	2.18E-04
CUMULAT TOT+ (Bq-d/kg)	1.67E-01	6.54E-01	7.92E-02	7.92E-02	7.97E-02

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	1.47E+00	4.33E+00	1.17E+00	4.07E+01	5.04E+01	---	---
BEEF	1.12E-02	4.41E-02	8.42E-04	2.16E+00	1.51E-01	2.37E+00	2.37E+00
MILK (Bq-d/L)	2.80E-03	1.10E-02	2.10E-04	5.40E-01	3.78E-02	5.92E-01	5.92E-01
POULTRY	1.24E-01	---	1.04E-02	---	4.49E-01	5.84E-01	5.84E-01
OTHER	1.34E-02	3.94E-02	0.00E+00	3.52E+00	4.60E-01	4.04E+00	4.04E+00

---

71. DAY INTEGRATED MILK CONCENTRATION FROM PASTURE (Bq-d/L): 5.25E-01

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	1.63E-06	3.41E-05	1.89E-06	1.89E-06	1.65E-06
SURFACE SOIL (Bq/m**2)	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.14E-04
LABILE SOIL (Bq/m**2)	3.93E-02	3.93E-02	3.93E-02	3.93E-02	3.93E-02
FIXED SOIL (Bq/m**2)	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08
VEGETATION INT (Bq/kg)	7.43E-06	4.56E-06	2.54E-06	2.54E-06	2.77E-06
VEGETATION TOT (Bq/kg)	9.06E-06	3.87E-05	4.44E-06	4.44E-06	4.43E-06
CUMULAT TOT+ (Bq-d/kg)	7.13E-03	2.91E-02	3.43E-03	3.43E-03	3.44E-03

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	4.90E-02	1.57E-01	3.95E-02	2.72E-01	3.64E-01	---	---
BEEF	1.38E-02	5.94E-02	1.05E-03	5.34E-01	4.04E-02	6.48E-01	6.48E-01
MILK (Bq-d/L)	2.69E-02	1.16E-01	2.05E-03	1.04E+00	7.87E-02	1.26E+00	1.26E+00
POULTRY	4.14E-03	---	3.52E-04	---	3.25E-03	7.74E-03	7.74E-03
OTHER	4.47E-04	1.44E-03	0.00E+00	2.35E-02	3.32E-03	2.87E-02	2.87E-02

---

71. DAY INTEGRATED MILK CONCENTRATION FROM PASTURE (Bq-d/L): 4.25E+01

============== RESULTS FOR ACCIDENT YEAR NUMBER 2==================

RESULTS FOR MEMBER # 1	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	9.07E-06	1.90E-04	1.06E-05	1.06E-05	9.09E-06

SURFACE SOIL (Bq/m**2)	3.36E-04	3.37E-04	3.37E-04	3.37E-04	3.37E-04
LABILE SOIL (Bq/m**2)	7.68E-01	7.87E-01	7.87E-01	7.87E-01	7.75E-01
FIXED SOIL (Bq/m**2)	5.21E-07	5.27E-07	5.27E-07	5.27E-07	5.22E-07
VEGETATION INT (Bq/kg)	1.96E-02	3.27E-02	1.82E-02	1.82E-02	1.83E-02
VEGETATION TOT (Bq/kg)	1.96E-02	3.28E-02	1.82E-02	1.82E-02	1.83E-02
CUMULAT TOT+ (Bq-d/kg)	7.33E+00	1.26E+01	6.73E+00	6.73E+00	6.77E+00

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	2.69E+01	3.77E+00	2.50E+01	8.95E-02	6.77E-02	---	---
BEEF	2.05E-01	3.85E-02	1.80E-02	4.75E-03	2.03E-04	2.66E-01	2.63E+00
MILK (Bq-d/L)	5.13E-02	9.62E-03	4.49E-03	1.19E-03	5.08E-05	6.66E-02	6.59E-01
POULTRY	2.28E+00	---	2.22E-01	---	6.03E-04	2.50E+00	3.08E+00
OTHER	2.45E-01	3.44E-02	0.00E+00	7.75E-03	6.18E-04	2.88E-01	4.33E+00

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	6.22E-07	1.31E-05	7.26E-07	7.26E-07	6.25E-07
SURFACE SOIL (Bq/m**2)	2.91E-05	2.92E-05	2.92E-05	2.92E-05	2.92E-05
LABILE SOIL (Bq/m**2)	7.49E-02	7.58E-02	7.57E-02	7.57E-02	7.52E-02
FIXED SOIL (Bq/m**2)	4.69E-08	4.73E-08	4.72E-08	4.72E-08	4.70E-08
VEGETATION INT (Bq/kg)	4.58E-04	7.96E-04	4.44E-04	4.44E-04	4.44E-04
VEGETATION TOT (Bq/kg)	4.58E-04	8.09E-04	4.44E-04	4.44E-04	4.45E-04
CUMULAT TOT+ (Bq-d/kg)	3.38E-01	5.97E-01	3.17E-01	3.17E-01	3.18E-01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	9.90E-01	2.23E-01	9.37E-01	4.35E-03	4.00E-03	---	---
BEEF	2.79E-01	8.41E-02	2.50E-02	8.54E-03	4.44E-04	3.97E-01	1.05E+00
MILK (Bq-d/L)	5.43E-01	1.64E-01	4.86E-02	1.66E-02	8.63E-04	7.73E-01	2.03E+00
POULTRY	8.38E-02	---	8.35E-03	---	3.56E-05	9.21E-02	9.99E-02
OTHER	9.02E-03	2.03E-03	0.00E+00	3.77E-04	3.65E-05	1.15E-02	4.02E-02

============== RESULTS FOR ACCIDENT YEAR NUMBER 15==================

RESULTS FOR MEMBER # 1	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	7.21E-07	2.06E-05	1.14E-06	1.14E-06	8.07E-07
SURFACE SOIL (Bq/m**2)	2.67E-05	3.66E-05	3.65E-05	3.65E-05	2.99E-05
LABILE SOIL (Bq/m**2)	6.10E-02	8.54E-02	8.52E-02	8.52E-02	6.88E-02
FIXED SOIL (Bq/m**2)	1.70E-06	1.87E-06	1.87E-06	1.87E-06	1.76E-06
VEGETATION INT (Bq/kg)	1.56E-03	3.54E-03	1.97E-03	1.97E-03	1.63E-03
VEGETATION TOT (Bq/kg)	1.56E-03	3.56E-03	1.97E-03	1.97E-03	1.63E-03
CUMULAT TOT+ (Bq-d/kg)	3.80E+01	7.00E+01	3.85E+01	3.85E+01	3.65E+01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	4.20E+00	4.04E-04	4.36E+00	1.98E-02	1.85E-03	---	---
BEEF	3.20E-02	4.12E-06	3.14E-03	1.05E-03	5.54E-06	3.62E-02	4.54E+00
MILK (Bq-d/L)	7.99E-03	1.03E-06	7.84E-04	2.63E-04	1.39E-06	9.04E-03	1.13E+00
POULTRY	3.55E-01	---	3.88E-02	---	1.65E-05	3.94E-01	2.42E+01
OTHER	3.83E-02	3.68E-06	0.00E+00	1.72E-03	1.68E-05	4.00E-02	6.43E+00

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	1.40E-06	3.30E-05	1.83E-06	1.83E-06	1.47E-06
SURFACE SOIL (Bq/m**2)	5.15E-05	5.80E-05	5.79E-05	5.79E-05	5.39E-05
LABILE SOIL (Bq/m**2)	1.42E-01	1.59E-01	1.59E-01	1.59E-01	1.48E-01
FIXED SOIL (Bq/m**2)	1.15E-06	1.24E-06	1.23E-06	1.23E-06	1.18E-06
VEGETATION INT (Bq/kg)	3.69E-05	8.72E-05	4.84E-05	4.84E-05	3.99E-05
VEGETATION TOT (Bq/kg)	3.83E-05	1.20E-04	5.03E-05	5.03E-05	4.13E-05
CUMULAT TOT+ (Bq-d/kg)	1.76E+00	3.45E+00	1.83E+00	1.83E+00	1.73E+00

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	2.33E-01	3.48E-04	2.45E-01	3.48E-04	6.31E-05	---	---
BEEF	6.56E-02	1.31E-04	6.54E-03	6.84E-04	7.00E-06	7.30E-02	4.48E+00
MILK (Bq-d/L)	1.28E-01	2.56E-04	1.27E-02	1.33E-03	1.36E-05	1.42E-01	8.71E+00
POULTRY	1.97E-02	---	2.19E-03	---	5.62E-07	2.19E-02	1.14E+00
OTHER	2.12E-03	3.18E-06	0.00E+00	3.01E-05	5.75E-07	2.16E-03	1.42E-01

+ Cumulative 365 day integrated concentration in food products from the time of the accident.

++ Animal feed inventories are corrected for hold-up time from time of harvest to animal consumption time. Animal product concentrations are corrected for decay of the parent nuclide from production (slaughter) to human consumption.

EXECUTION TIME (seconds) 61

COMIDA.PAR input file for release event occurring in summer.

```
'SAMPLE PROBLEM FOR SANDIA NAT LAB USING MO-93 AND NB-93 PROGENY SUMMER ACCIDENT ' TITLE
0.10  1.00  0.10  0.10   0.10                      TVC(I),I=1,5
0.12  0.12   0.12  0.12  0.12                      ZKGC(I),I=1,5
0.015 0.039   0.039  0.039  0.039                  BIC(I),I=1,5
0.73  0.628  0.628 0.628 0.73                      BMAXC(I),I=1,5
0.73  0.628  0.628 0.628 0.73                      BSTAND(I),I=1,5
0.15  0.27   0.15  0.15  0.15                      FD(I),I=1,5
0.035 0.120                                        ZKGP ZSEN
0.07   0.30                                        BIP BMAXP
0.27 0.08  0.628                                   ZKGH BIH BMAXH
3  170. 230. 290.                                  NCUT (TCUT(I),I=1,NCUT)
8.85 1.7  1.27 0.5  1.2e-1                         RPB RHB RGB RSB RLB
8.85 1.7  1.27 0.5  1.2e-1                         RPM RHM RGM RSM RLM
0.095  0.01  0.01                                  RGPL RLPL RSPL
0.095 0.01 0.01    0.01  0.0                       RPO RHHO RGO RSO RLO
1.98E-2  5.7E-2  1.73E-3  8.6E-4                   ZKP,ZKW,ZKR,Zkrs
1000.0 1400. 0.25  0.001 0.39                      PSS,PSR,XR,XS ALPHA
2.60 2.60 2.60 2.60 2.60 2.60 2.60                 ALPHA(I),I=1,7
71.  65. 75. 110. 111.                             TINTM TT,TSC,TSP,TSL
120. 290.  300.  210.                              TSH TEC,TEL,TI
0.,0.,0.,0.,0.,0.                                  THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
3 1 2 15                                            NTIMES KYEAR
```

COMIDA output file for release event occurring in summer.

```
@(#)main.f       1.4  1/19/93  09:59:00\0
@(#)inputpar.f  1.8  10/25/93  10:24:34\0
TIME: 11:52:09.17
DATE: 10/25/93
TITLE:
SAMPLE PROBLEM FOR SANDIA NAT LAB USING MO-93 AND NB-93 PROGENY SUMMER ACCIDENT
   ******************** COMIDA **********************
   * A dynamic food chain model for use in the MACCS *
   *          reactor consequence code.              *
   *      Arthur S. Rood and Michael L. Abbott       *
   *     Idaho National Engineering Laboratory       *
   *      EG&G Idaho PO Box 1625 Idaho Falls         *
   *                  ID 83401.                      *
   *             Version Control Copy                *
   *         Version 1.01  October 25, 1993          *
   ***************************************************
  ==========================================================================
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  ==========================================================================
```

PARAMETER VALUES FOR COMIDA

------ CROP VALUES ------

	GRAINS	LEAFY VEGETABLES	ROOT CROPS	FRUITS	LEGUMES
INTERCEPTION FRAC (m**2/kg):	2.60E+00	2.60E+00	2.60E+00	2.60E+00	2.60E+00
FRACTION TO EDIBLE PORTION OF CROP:	1.00E-01	1.00E+00	1.00E-01	1.00E-01	1.00E-01
GROWTH RATE CONSTANT (d-1):	1.20E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01
INITIAL CROP BIOMASS (kg(dry)/m**2):	1.50E-02	3.90E-02	3.90E-02	3.90E-02	3.90E-02
MAXIMUM CROP BIOMASS (kg(dry)/m**2):	7.30E-01	6.28E-01	6.28E-01	6.28E-01	7.30E-01
STANDING CROP BIOMASS (kg(dry)/m**2):	7.30E-01	6.28E-01	6.28E-01	6.28E-01	7.30E-01
DRY WEIGHT TO WET WEIGHT RATIO:	1.50E-01	2.70E-01	1.50E-01	1.50E-01	1.50E-01

------ ANIMAL FEED PARAMETERS ------	GRAINS	LEGUMES	HAY	PASTURE*	SOIL
GROWTH RATE CONSTANT (d**-1):	---	---	2.70E-01	3.50E-02	---
INITIAL CROP BIOMASS (kg(dry)/m**2):	---	---	8.00E-02	7.00E-02	---
MAXIMUM CROP BIOMASS (kg(dry)/m**2):	---	---	6.28E-01	3.00E-01	---
FOLIAR INTERCEPTION FRAC (m**2/kg):	---	---	2.60E+00	2.60E+00	---
SENESCENCE RATE CONSTANT (d-1):	---	---	---	1.20E-01	---
ANNUAL AVG BEEF COW CONSUMPTION (kg/d):	1.27E+00	1.20E-01	1.70E+00	8.85E+00	5.00E-01
ANNUAL AVG MILK COW CONSUMPTION (kg/d):	1.27E+00	1.20E-01	1.70E+00	8.85E+00	5.00E-01
ANNUAL AVG POULTRY CONSUMPTION (kg/d):	9.50E-02	1.00E-02	---	---	1.00E-02
ANNUAL AVG OTHER ANIMAL CONSUMP (kg/d):	1.00E-02	0.00E+00	1.00E-02	9.50E-02	1.00E-02

* ingestion rate only while animal is on pasture

----- OTHER FEED PARAMETERS -----

NUMBER OF HAY CUTTINGS:	3
HAY CUTTING TIMES (JULIAN DAY):	170. 230. 290.
SHORT TERM PASTURE INT. TIME FOR MILK (d):	7.10E+01

------ SOIL PARAMETERS ------

PERCOLATION RATE CONSTANT (d**-1):	1.98E-02
WEATHERING RATE CONSTANT (d**-1):	5.70E-02
RESUSPENTION RATE CONSTANT (d**-1):	1.73E-03
RAINSPLASH RATE CONSTANT (d**-1):	8.60E-04
SURFACE SOIL DENSITY (kg/m**3):	1.00E+03
ROOT SOIL DENSITY (kg/m**3):	1.40E+03
DEPTH OF ROOTING ZONE (m):	2.50E-01
SURFACE SOIL COMPARTMENT THICKNESS (m):	1.00E-03

------ TIME PARAMETERS ------

TIME OF TILLAGE (JULIAN DAY):	65.
START OF CROP GROWING SEASON (JULIAN DAY):	75.
START OF PASTURE GROWING SEASON (JULIAN DAY):	110.
START OF GRAZING SEASON (JULIAN DAY):	111.
START OF HAY GROWING SEASON (JULIAN DAY):	120.
END OF CROP GROWING SEASON (JULIAN DAY):	290.
END OF GRAZING SEASON (JULIAN DAY):	300.
TIME OF FALLOUT EVENT (JULIAN DAY):	210.
HOLD-UP TIME, BEEF (DAYS):	0.
HOLD-UP TIME, MILK (DAYS):	0.
HOLD-UP TIME, POULTRY (DAYS):	0.
HOLD-UP TIME, OTHER ANIMAL (DAYS):	0.
HOLD-UP TIME, ANIMAL FEED GRAIN&LEGUME (DAYS):	0.
HOLD-UP TIME, ANIMAL FEED HAY (DAYS):	0.

UNITS: CROP CONCENTRATION: Bq/kg (wet weight)
ANIMAL FEED COMPARTMENTS: Bq/m**2 (dry weight)
SOIL COMPARTMENTS: Bq/m**2
MILK: Bq-d/L
MEAT: Bq-d/kg

NUMBER OF NUCLIDES EVALUATED 1

PARENT NUCLIDE NAME: MO-93 NUMBER OF PROGENY: 1

SOIL ADSORPTION RATE CONSTANT (d**-1) 1.00E-09

```
SOIL DESORPTION RATE CONSTANT (d**-1)  1.00E-09
NUMBER OF HALF LIVES TO CUTOFF         10
CUTOFF TIME (years)                    3.50E+04
----------------------------------------------
DATA FOR MEMBER # 1 MO-93  HALF LIFE (d)  1.277E+06  LEACH RATE (d**-1)  2.50E-04
   CROP TYPE >>>        GRAINS   LEAF VEG ROOT     FRUITS   LEGUMES  HAY      PASTURE
CONCENTRATION RATIO     7.00E+01 7.00E+01 7.03E+01 7.03E+01 7.03E+01 1.60E-03 2.00E-01
FOLIAR ABSORPTION       5.50E-09 5.50E-09 5.50E-09 5.50E-09 5.50E-09 1.00E-04 1.00E-09
   ANIMAL PRODUCT >>>   BEEF (d/kg) MILK (d/L)  POUL (d/kg) OTHER (d/kg)
TRANSFER COEFFICIENT    6.00E-03    1.50E-03    8.91E-01    9.12E-01

----------------------------------------------
DATA FOR MEMBER # 2 NB-93  HALF LIFE (d)  5.329E+03  LEACH RATE (d**-1)  1.45E-05
   CROP TYPE >>>        GRAINS   LEAF VEG ROOT     FRUITS   LEGUMES  HAY      PASTURE
CONCENTRATION RATIO     1.00E-02 1.00E-02 1.00E-02 1.00E-02 1.00E-02 1.60E-03 2.00E-03
FOLIAR ABSORPTION       5.50E-09 5.50E-09 5.50E-09 5.50E-09 5.50E-09 1.00E-02 2.30E-02
   ANIMAL PRODUCT >>>   BEEF (d/kg) MILK (d/L)  POUL (d/kg) OTHER (d/kg)
TRANSFER COEFFICIENT    2.22E-01    4.32E-01    8.91E-01    9.12E-01

============== RESULTS FOR ACCIDENT YEAR NUMBER   1=================
RESULTS FOR MEMBER #  1 GRAINS   LEAF VEG   ROOT     FRUITS   LEGUMES

VEGETATION SURF (Bq/kg) 5.23E-04 1.07E-02 5.93E-04 5.93E-04 5.23E-04
SURFACE SOIL (Bq/m**2)  1.45E-02 1.43E-02 1.43E-02 1.43E-02 1.45E-02
LABILE SOIL (Bq/m**2)   9.20E-01 9.21E-01 9.21E-01 9.21E-01 9.20E-01
FIXED SOIL (Bq/m**2)    1.58E-07 1.59E-07 1.59E-07 1.59E-07 1.58E-07
VEGETATION INT (Bq/kg)  2.59E-08 4.09E-08 2.27E-08 2.27E-08 2.10E-08
VEGETATION TOT (Bq/kg)  5.23E-04 1.07E-02 5.93E-04 5.93E-04 5.23E-04
CUMULAT TOT+ (Bq-d/kg)  1.91E-01 3.89E+00 2.16E-01 2.16E-01 1.91E-01
---------------------
INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)
                 GRAIN      HAY      LEGUME    PASTURE  SOIL      TOTAL    CUMULATIVE

ANIMAL FEED      9.94E+00 4.27E+01 9.94E+00 3.69E+01 5.04E+01  ---        ---
BEEF             7.57E-02 4.36E-01 7.16E-03 1.96E+00 1.51E-01 2.63E+00 2.63E+00
MILK (Bq-d/L)    1.89E-02 1.09E-01 1.79E-03 4.89E-01 3.78E-02 6.57E-01 6.57E-01
POULTRY          8.41E-01  ---     8.85E-02  ---     4.49E-01 1.38E+00 1.38E+00
OTHER            9.06E-02 3.90E-01 0.00E+00 3.19E+00 4.60E-01 4.13E+00 4.13E+00
---------------------
 71. DAY INTEGRATED MILK CONCENTRATION FROM PASTURE (Bq-d/L):  4.95E-01
RESULTS FOR MEMBER #  2 GRAINS   LEAF VEG   ROOT     FRUITS   LEGUMES

VEGETATION SURF (Bq/kg) 5.41E-06 1.10E-04 6.14E-06 6.14E-06 5.41E-06
SURFACE SOIL (Bq/m**2)  4.26E-04 4.20E-04 4.20E-04 4.20E-04 4.26E-04
LABILE SOIL (Bq/m**2)   2.78E-02 2.78E-02 2.78E-02 2.78E-02 2.78E-02
FIXED SOIL (Bq/m**2)    4.70E-09 4.73E-09 4.73E-09 4.73E-09 4.70E-09
VEGETATION INT (Bq/kg)  2.49E-10 4.12E-10 2.29E-10 2.29E-10 2.11E-10
VEGETATION TOT (Bq/kg)  5.42E-06 1.10E-04 6.14E-06 6.14E-06 5.42E-06
CUMULAT TOT+ (Bq-d/kg)  6.39E-03 1.30E-01 7.24E-03 7.24E-03 6.39E-03
---------------------
INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)
                 GRAIN      HAY      LEGUME    PASTURE  SOIL      TOTAL    CUMULATIVE

ANIMAL FEED      2.83E-01 1.23E+00 2.83E-01 1.71E-01 3.98E-01  ---        ---
BEEF             7.98E-02 4.62E-01 7.54E-03 3.35E-01 4.42E-02 9.29E-01 9.29E-01
MILK (Bq-d/L)    1.55E-01 9.00E-01 1.47E-02 6.52E-01 8.60E-02 1.81E+00 1.81E+00
POULTRY          2.40E-02  ---     2.52E-03  ---     3.55E-03 3.00E-02 3.00E-02
OTHER            2.58E-03 1.12E-02 0.00E+00 1.48E-02 3.63E-03 3.22E-02 3.22E-02
---------------------
 71. DAY INTEGRATED MILK CONCENTRATION FROM PASTURE (Bq-d/L):  6.20E+01
============== RESULTS FOR ACCIDENT YEAR NUMBER   2=================
RESULTS FOR MEMBER #  1 GRAINS   LEAF VEG   ROOT     FRUITS   LEGUMES

VEGETATION SURF (Bq/kg) 9.08E-06 1.90E-04 1.06E-05 1.06E-05 9.10E-06
SURFACE SOIL (Bq/m**2)  3.37E-04 3.37E-04 3.37E-04 3.37E-04 3.37E-04
```

LABILE SOIL (Bq/m**2)	7.69E-01	7.88E-01	7.88E-01	7.88E-01	7.76E-01
FIXED SOIL (Bq/m**2)	4.35E-07	4.41E-07	4.41E-07	4.41E-07	4.36E-07
VEGETATION INT (Bq/kg)	1.97E-02	3.27E-02	1.82E-02	1.82E-02	1.83E-02
VEGETATION TOT (Bq/kg)	1.97E-02	3.29E-02	1.82E-02	1.82E-02	1.83E-02
CUMULAT TOT+ (Bq-d/kg)	7.37E+00	1.59E+01	6.87E+00	6.87E+00	6.88E+00

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	4.03E+01	1.20E+01	3.78E+01	7.74E-02	7.60E-02	---	---
BEEF	3.07E-01	1.23E-01	2.72E-02	4.11E-03	2.28E-04	4.61E-01	3.09E+00
MILK (Bq-d/L)	7.68E-02	3.06E-02	6.80E-03	1.03E-03	5.70E-05	1.15E-01	7.72E-01
POULTRY	3.41E+00	---	3.37E-01	---	6.77E-04	3.75E+00	5.13E+00
OTHER	3.68E-01	1.10E-01	0.00E+00	6.70E-03	6.93E-04	4.85E-01	4.62E+00

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	5.17E-07	1.09E-05	6.03E-07	6.03E-07	5.18E-07
SURFACE SOIL (Bq/m**2)	2.53E-05	2.54E-05	2.54E-05	2.54E-05	2.54E-05
LABILE SOIL (Bq/m**2)	6.44E-02	6.52E-02	6.51E-02	6.51E-02	6.46E-02
FIXED SOIL (Bq/m**2)	3.42E-08	3.45E-08	3.45E-08	3.45E-08	3.42E-08
VEGETATION INT (Bq/kg)	4.59E-04	7.96E-04	4.44E-04	4.44E-04	4.44E-04
VEGETATION TOT (Bq/kg)	4.59E-04	8.07E-04	4.45E-04	4.45E-04	4.45E-04
CUMULAT TOT+ (Bq-d/kg)	3.38E-01	6.98E-01	3.21E-01	3.21E-01	3.21E-01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	1.69E+00	6.20E-01	1.62E+00	6.59E-03	4.37E-03	---	---
BEEF	4.78E-01	2.34E-01	4.32E-02	1.30E-02	4.85E-04	7.68E-01	1.70E+00
MILK (Bq-d/L)	9.30E-01	4.55E-01	8.41E-02	2.52E-02	9.44E-04	1.50E+00	3.30E+00
POULTRY	1.43E-01	---	1.45E-02	---	3.89E-05	1.58E-01	1.88E-01
OTHER	1.55E-02	5.65E-03	0.00E+00	5.71E-04	3.98E-05	2.17E-02	5.39E-02

============== RESULTS FOR ACCIDENT YEAR NUMBER 15=================

RESULTS FOR MEMBER # 1	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	7.22E-07	2.07E-05	1.14E-06	1.14E-06	8.08E-07
SURFACE SOIL (Bq/m**2)	2.68E-05	3.66E-05	3.65E-05	3.65E-05	2.99E-05
LABILE SOIL (Bq/m**2)	6.12E-02	8.55E-02	8.52E-02	8.52E-02	6.89E-02
FIXED SOIL (Bq/m**2)	1.62E-06	1.79E-06	1.79E-06	1.79E-06	1.67E-06
VEGETATION INT (Bq/kg)	1.56E-03	3.55E-03	1.97E-03	1.97E-03	1.63E-03
VEGETATION TOT (Bq/kg)	1.56E-03	3.57E-03	1.97E-03	1.97E-03	1.63E-03
CUMULAT TOT+ (Bq-d/kg)	3.81E+01	7.33E+01	3.87E+01	3.87E+01	3.67E+01

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	4.00E+00	3.03E-04	4.16E+00	1.95E-02	1.89E-03	---	---
BEEF	3.05E-02	3.09E-06	2.99E-03	1.04E-03	5.66E-06	3.45E-02	4.91E+00
MILK (Bq-d/L)	7.62E-03	7.72E-07	7.48E-04	2.59E-04	1.41E-06	8.63E-03	1.23E+00
POULTRY	3.39E-01	---	3.70E-02	---	1.68E-05	3.76E-01	2.52E+01
OTHER	3.65E-02	2.76E-06	0.00E+00	1.69E-03	1.72E-05	3.82E-02	6.62E+00

RESULTS FOR MEMBER # 2	GRAINS	LEAF VEG	ROOT	FRUITS	LEGUMES
VEGETATION SURF (Bq/kg)	1.35E-06	3.19E-05	1.77E-06	1.77E-06	1.41E-06
SURFACE SOIL (Bq/m**2)	4.97E-05	5.61E-05	5.60E-05	5.60E-05	5.19E-05
LABILE SOIL (Bq/m**2)	1.37E-01	1.54E-01	1.54E-01	1.54E-01	1.43E-01
FIXED SOIL (Bq/m**2)	1.08E-06	1.17E-06	1.16E-06	1.16E-06	1.11E-06
VEGETATION INT (Bq/kg)	3.69E-05	8.72E-05	4.85E-05	4.85E-05	3.99E-05
VEGETATION TOT (Bq/kg)	3.83E-05	1.19E-04	5.02E-05	5.02E-05	4.13E-05
CUMULAT TOT+ (Bq-d/kg)	1.76E+00	3.54E+00	1.83E+00	1.83E+00	1.73E+00

INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/kg)

	GRAIN	HAY	LEGUME	PASTURE	SOIL	TOTAL	CUMULATIVE
ANIMAL FEED	2.21E-01	2.61E-04	2.33E-01	3.49E-04	6.40E-05	---	---
BEEF	6.22E-02	9.85E-05	6.21E-03	6.85E-04	7.10E-06	6.92E-02	4.95E+00
MILK (Bq-d/L)	1.21E-01	1.92E-04	1.21E-02	1.33E-03	1.38E-05	1.35E-01	9.63E+00
POULTRY	1.87E-02	---	2.08E-03	---	5.70E-07	2.08E-02	1.17E+00
OTHER	2.01E-03	2.38E-06	0.00E+00	3.02E-05	5.84E-07	2.05E-03	1.50E-01

\+ Cumulative 365 day integrated concentration in food products from the time of the accident.

++ Animal feed inventories are corrected for hold-up time from time of harvest to animal consumption time. Animal product concentrations are corrected for decay of the parent nuclide from production (slaughter) to human consumption.

EXECUTION TIME (seconds) 59

APPENDIX B: COMIDA Code Listing

```
      PROGRAM COMIDA
      IMPLICIT REAL*8 (A-H,O-Z)
C The folloing integer variables are only used in for the PC version
      INTEGER*4 ITICK1,ITICK2,ITICK
*
*     Identification
*     Program Name: COMIDA
*     Module Name: main.f Version 1.4
*     Date: 1/19/93 Time: 09:59:00
*
      Character idkeyw*72
      Data idkeyw /'@(#)main.f          1.4  1/19/93  09:59:00\0'/

C *******************************************************
C * NOTE: For compilation on the INEL CRAY:             *
C * Replace integer ITICK variables with real TICK variables *
C * Replace "TIMER" functions with the "SECOND" function   *
C * Change REAL*8 FUNCTION EXPF( to FUNCTION EXPF(        *
C *******************************************************
C   Concentration of Radionuclides In Food and Animal Products
C   **********************************************************
C   * This program was designed to calculate concentration in food *
C   * products for the MACCS code.  A. S. Rood
C   **********************************************************

C          DEFINITION OF VARIABLES USED IN COMIDA
C NOTE: I CORRESPONDS TO THE FOLLOWING I=1,GRAINS I=2 LEAFY VEG
C     I=3,ROOT CROPS I=4,FRUITS I=5,LEGUMES, I=6,HAY I=7,PASTURE
C     J CORRESPONGS TO THE NUMBER OF PROGENY
C                Define State Variables
c                --------------
C --crops
C   QVSC(I,J)=ACTIVITY CONCENTRATION ON CROP SURFACE (BQ/M2)
C   QSSC(I,J)=ACTIVITY CONCETRATION IN CROP SURFACE SOIL (BQ/M2)
C   QRSC(I,J)=ACTIVITY CONCENTRATION IN CROP ROOT ZONE (BQ/M2)
C   QVIC(I,J)=ACTIVITY CONCENTRATION IN CROP INTERIOR (BQ/M2)
C   QFSC(I,J)=ACTIVITY CONCENTRATION IN FIXED SOIL COMPARTMENT (BQ/M2)
C --pasture (grass)
C   QVSP(J)=ACTIVITY CONCENTRATION ON GRASS SURFACE (BQ/M2), Y(5)
C   QSSP(J)=ACTIVITY CONCETRATION IN GRASS SURFACE SOIL (BQ/M2), Y(6)
C   QRSP(J)=ACTIVITY CONCENTRATION IN GRASS ROOT ZONE (BQ/M2), Y(7)
C   QVIP(J)=ACTIVITY CONCENTRATION IN GRASS INTERIOR (BQ/M2) Y(8)
C   QFSP(J)=ACTIVITY CONCENTRATION IN FIXED SOIL COMPARTMENT (BQ/M2)
C --stored hay
C   QVSH(J)=ACTIVITY CONCENTRATION ON HAY SURFACE (BQ/M2), Y(9)
C   QSSH(J)=ACTIVITY CONCETRATION IN HAY SURFACE SOIL (BQ/M2), Y(10)
C   QRSH(J)=ACTIVITY CONCENTRATION IN HAY ROOT ZONE (BQ/M2), Y(11)
C   QVIH(J)=ACTIVITY CONCENTRATION IN HAY INTERIOR (BQ/M2) Y(12)
C   QFSH(J)=ACTIVITY CONCENTRATION IN FIXED SOIL COMPARTMENT (BQ/M2)
C          Calculated values from State Variables
C          ------------------------
C -- integrated and summed values-pasture
C   QTIP(J)=TOTAL INTEGRATED ACTIVITY IN PASTURE GRASS FOR EACH ACCIDENT YR (BQ-D/KG)
C   QSTIP(J)=SHORT TERM INTEGRATED PASTURE ACTIVITY (BQ-D/KG)
C   QSTIS(J)=SHORT TERM INTEGRATED PASTURE SOIL ACTIVITY (BQ-D/KG)
C   QIPS(J)=INTEGRATED ACTIVITY IN PASTURE SURFACE SOIL (BQ-D/KG)
C -- integrated and summed values-crops
C   QTIC(I,J)=TOTAL (internal and surface) 365 D INTEGRATED CROP ACTIVITY (BQ-D/KG wet weight)
C   QTIG(J)=TOTAL (internal and surface) INTEGRATED ACTIVITY IN STORED ANIMAL FEED GRAIN (BQ-D/KG dry weight) FOR 1 ACCIDENT YEAR
C   QTIL(J)=TOTAL (internal and surface) INTEGRATED ACTIVTIY IN STORED ANIMAL FEED LEGUMES (BQ-D/KG dry weight) FOR 1 ACCIDENT YEAR
C   CTOTAL(I,J)=TOTAL (internal and surface) ACTIVITY IN CROPS AT HARVEST FOR I=1 TO 5 (BQ/KG wet weight)
C   CTOTAL(I,J)=TOTAL ACTIVITY IN GRAIN (I=6) AND LEGUME (I=7) ANIMAL FEEDS (BQ/KG dry weight)
C   note: CTOTAL(6,J) and CTOTAL(7,J) are not corrected for surface translocation.
C   TQC(J)=CUMULATIVE TOTAL (internal and external) 365 DAY INTEGRATED CROP ACTIVITY (BQ-D/KG wet weight)
C   PGRAIN(J)=PRIOR YEARS ACTIVITY INVENTORY IN GRAIN (BQ/KG dry weight)
C   PLEGUME(J)=PRIOR YEARS ACTIVITY INVENTORY IN LEGUME (BQ/KG dry weight)
C -- integrated and summed values-hay
C   QTIH(J)=TOTAL INTEGRATED ACTIVITY IN STORED HAY (BQ-D/KG)
C   PHAY(J)=PRIOR YEARS ACTIVITY INVENTORY IN HAY (BQ/KG)
C -- beef
C   QIBP(J)=INTEGRATED ACTIVITY CONCENTRATION IN BEEF FROM PASTURE GRASS (BQ-D/KG)
C   QIBH(J)=INTEGRATED ACTIVITY CONCETRATION IN BEEF FROM STORED HAY (BQ-D/KG)
C   QIBG(J)=INTEGRATED ACTIVITY CONCENTRATION IN BEEF FROM GRAIN (BQ-D/KG)
C   QIBL(J)=INTEGRATED ACTIVITY CONCENTRATION IN BEEF FROM LEGUMES (BQ-D/KG)
C   QIBS(J)=INTEGRATED ACTIVITY CONCENTRATION IN BEEF FROM SOIL (BQ-D/KG)
C   QIBT(J)=INTEGRATED TOTAL ACTIVITY CONCENTRATION IN BEEF PASTURE,HAY,GRAIN (BQ-D/KG)
C   TQB=TOTAL INTEGRATED ACTIVITY IN BEEF FOR ALL YERAS CONSIDERED
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C — milk
C   QIMP(J) = ACTIVITY CONCENTRATION IN MILK FROM GRASS CONTRIBUTIONS (BQ-D/L)
C   QIMH(J) = ACTIVITY CONCETRATION IN MILK FROM FEED CONTRIBUTIONS (BQ-D/L)
C   QIMG(J) = ACTIVITY CONCENTRATION IN MILK FROM GRAIN (BQ-D/L)
C   QIML(J) = ACTIVITY CONCENTRATION IN MILK FROM LEGUMES (BQ-D/L)
C   QIMS(J) = ACTIVITY CONCENTRATION IN MILK FROM SOIL (BQ-D/L)
C   QIMT(J) = TOTAL ACTIVITY CONCENTRATION IN MILK PASTURE,HAY,GRAIN (BQ-D/L)
C   QISM(J) = SHORT TERM INTEGRATED MILK CONCENTRATION FROM PASTURE (Bq-d/kg)
C   TQM = TOTAL INTEGRATED ACTIVITY IN MILK FOR ALL YERAS CONSIDERED
C — poultry
C   QIPLG(J) = ACTIVITY CONCENTRATION IN POULTRY FROM GRAIN (BQ-D/KG)
C   QIPLS(J) = ACTIVITY CONCENTRATION IN POULTRY FROM SOIL (BQ-D/KG)
C   QIPLL(J) = ACTIVITY CONCENTRATION IN POULTRY FROM LEGUMES (BQ-D/KG)
C   QTIPL(J) = TOTAL ACTIVITY CONCENTRATION IN POULTRY (BQ-d/KG)
C   TQP = TOTAL INTEGRATED ACTIVITY IN POULTRY FOR ALL YERAS CONSIDERED (BQ-D/KG)
C — other aniaml
C   QIOG(J) = ACTIVITY CONCENTRATION IN OTHER ANIMAL FROM GRAIN (BQ-D/KG)
C   QIOS(J) = ACTIVITY CONCENTRATION IN OTHER ANIMAL FROM SOIL (BQ-D/KG)
C   QIOP(J) = INTEGRATED ACTIVITY CONCENTRATION IN OTHER ANIMAL FROM PASTURE GRASS (BQ-D/KG)
C   QIOH(J) = INTEGRATED ACTIVITY CONCETRATION IN OTHER ANIMAL FROM STORED HAY (BQ-D/KG)
C   QIOL(J) = INTEGRATED ACTIVITY CONCENTRATION IN OTHER ANIMAL FROM LEGUMES (BQ-D/KG)
C   QTIO(J) = TOTAL ACTIVITY CONCENTRATION IN OTHER ANIMAL (BQ-D/KG)
C   TQO = TOTAL INTEGRATED ACTIVITY IN OTHER ANIMAL FOR ALL YERAS CONSIDERED (BQ-D/KG)
C               Other Calculated Values
C               -----------------------
C   D(J) = RADIONUCLIDE DECAY CONSTANT (d-1)
C   NMEMBER = NUMBER OF MEMBERS OF DECAY CHAIN = NPROG + 1
C   crop
C   FVC(I) = FALLOUT FRACTION TO CROP SURFACE
C   FSC(I) = FALLOUT FRACTION TO CROP SOIL SURFACE
C   pasture
C   FVP = FALLOUT FRATION TO PASTURE SURFACE
C   FSP = FALLOUT FRACTION TO PASTURE SOIL
C   hay
C   FVH = FALLOUT FRACTION TO HAY SURFACE
C   FVS = FALLOUT FRATION TO VEG SURFACE
C          Food Product and Nuclide Specific Input Values
C          ----------------------------------------------
C   NNUC = NUMBER OF NUCLIDES IN SIMULATION
C   NUC = RADIONUCLIDE ID
C   NPROG = NUMBER OF PROGENY
C   THALF(J) = HALF LIFE OF PARENT AND PROGENY
C   ZKL(J) = LEACH RATE CONSTANT (d-1)
C   ZKAD = ADSORPTION TO FIXED SOIL COMPARTMENT
C   ZKDE = DESORPTION FROM FIXED SOIL
C — crop
C   CRC(I,J) = CONCENTRATION RATIO FOR CROPS (dry weight)
C   TVC(I) = FRACTION OF SURFACE CONTAMINANTION ON EDIABLE PORTION OF CROP
C   ZKABC(I,J) = FOLIAR ABSORPTION RATE CONSTANT FOR CROPS (d-1)
C   ZKGC(I) = GROWTH RATE CONSTANT FOR CROP(d-1)
C   BIC(I) = INITIAL CROP BIOMASS AT START OF GROWING SEASON (KG(dry)/M2)
C   BMAXC(I) = MAXIMUM CROP BIOMASS (KG(dry)/M2)
C   BSTAND(I) = STANDING BIOMASS OF CROP (KG(dry)/M2)
C   FD(I) = DRY TO WET WEIGHT RATIO
C — pasture grass
C   CRP(J) = CONCENTRATION RATIO FOR PASTURE (dry weight)
C   ZKABP(J) = FOLIAR ABSORPTION RATE CONSTANT FOR PASTURE
C   ZKGP = GROWTH RATE CONSTANT FOR PASTURE(d-1)
C   BIP = INITIAL PASTURE BIOMASS AT START OF PASTURE SEASON (KG(dry)/M2)
C   BMAXP = MAXIMUM PASTURE BIOMASS (KG(dry)/M2)
C   ZSEN = SENESANCE RATE CONSTANT (d-1)
C — hay
C   CRH(J) = CONCENTRATION RATIO FOR HAY (dry weight)
C   ZKGH = GROWTH RATE CONSTANT FOR HAY(d-1)
C   ZKABH(J) = FOLIAR ABSORPTION RATE CONSTANT FOR HAY (d-1)
C   NCUT = NUMBER OF HAY CUTTINGS A YEAR (maximum of 3)
C   BIH = INITIAL HAY BIOMASS AT START OF SEASON (KG(dry)/M2)
C   BMAXH = MAXIMUM HAY BIOMASS (KG(dry)/M2)
C — beef
C   TCB(J) = BEEF TRANSFER COEFFICENT (d/kg)
C   RPB = BEEF DAILY INGESTION OF PASTURE (kg/d)
C   RHB = BEEF ANNUAL AVERAGE DAILY INGESTION OF HAY (kg/d)
C   RGB = BEEF ANNUAL AVERAGE DAILY INGESTION OF GRAIN (kg/d)
C   RSB = BEEF DAILY INGESTION RATE OF SOIL (kg/d)
C   RLB = BEEF DAILY INGESTION RATE OF LEGUMES (kg/d)
C — milk
C   TCM(J) = BEEF TRANSFER COEFFICENT (d/kg)
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C     RPM = MILK DAILY INGESTION OF PASTURE (kg/d)
C     RHM = MILK ANNUAL AVERAGE DAILY INGESTION OF HAY (kg/d)
C     RGM = MILK ANNUAL AVERAGE DAILY INGESTION OF GRAIN (kg/d)
C     RSM = MILK ANNUAL AVERAGE INGESTION RATE OF SOIL (kg/d)
C     RLM = MILK ANNUAL AVERAGE INGESTION RATE OF LEGUMES (kg/d)
C --- poultry
C     TCPL(J) = POULTRY TRANSFER COEFFICENT (d/kg)
C     RGPL = POULTRY GRAIN INGESTION RATE (kg/d)
C     RSPL = POULTRY SOIL INGESTION RATE (kg/d)
C --- other grain fed animal
C     TCO(J) = TRANSFER COEFFICNET FOR OTHER GRAIN FED ANIMAL (d/kg)
C     RGO = OTHER ANIMAL GRAIN INGESTION RATE (kg/d)
C     RSO = OTHER ANIMAL SOIL INGESTION RATE (kg/d)
C     RPO = OTHER ANIMAL DAILY INGESTION OF PASTURE (kg/d)
C     RHO = OTHER ANIMAL ANNUAL AVERAGE DAILY INGESTION OF HAY (kg/d)
C     RLO = OTHER ANIMAL DAILY INGESTION RATE OF LEGUMES (kg/d)

C         Input parameters not Specific to Crops or Nuclides
C         ------------------------------------------
C     ALPHA = RATIO OF VEG CONC TO TOTAL DEPOSITION (M^2/KG)
C     ZKP = PERCOLATION RATE CONSTANT (d-1)
C     ZKW = WETHERING RATE CONSTANT (d-1)
C     ZKR = RESUSPENTION RATE CONSTANT (d-1)
C     ZKRS = RAINSPLASH RATE CONSTANT (d-1)
C     PSS = SURFACE SOIL DENSITY (g/m3)
C     PSR = ROOT SOIL DENSITY (g/m3)
C     XR = DEPTH OF ROOTING ZONE (m)
C     XS = THICKNESS OF SURFACE SOIL COMPARTMENT (m)
C --- time variables
C     TINTM = SHORT TERM INTEGRATION TIME FOR MILK (d)
C     TT = TIME OF TILLAGE (JULIAN DAY)
C     TSC = START OF GROWING SEASON, CROPS (JULIAN DAY)
C     TSP = START OF PASTURE GROWING SEASON (JULIAN DAY)
C     TSL = START OF LIVESTOCK GRAZING SEASON (JULIAN DAY)
C     TSH = START OF HAY GROWING SEASON (JULIAN DAY)
C     TEC = END OF CROP GROWING SEASON (JULIAN DAY)
C     TEL = END OF LIVESTOCK GRAZING SEASON (JULIAN DAY)
C     TCUT(K) = TIME OF HAY CUTTING "K" (JULIAN DAY)
C     TI = TIME OF ACCIDENT (JULIAN DAY)
C     THOLDM = HOLDUP TIME, MILK
C     THOLDB = HOLDUP TIME, BEEF
C     THOLDP = HOLDUP TIME, POULTRY
C     THOLDO = HOLDUP TIME, OTHER
C     THOLDG = HOLDUP TIME, ANIMAL FEED-GRAIN
C     THOLDL = HOLDUP TIME, ANIMAL FEED-LEGUMES
C     THOLDH = HOLDUP TIME, ANIMAL FEED-HAY
C     ETIME = ELASPED TIME SINCE ACCIDENT
C     NTIMES = NUMBER OF YEARS TO CALCULATE RESULTS
C     KYEAR(NTIMES) = YEAR NUMBER RESULTS ARE CALCULATED FOR
C     CUTOFF = NUMBER OF HALF-LIVES CALCULATION IS TO BE PERFORMED OVER
C --- Parameters Values
C     NMAX = MAXIMUM NUMBER OF VARIABLES IN SOLVER (32)
C     MAXP = MAXIMUM NUMBER OF PROGENY (3 + PARENT)
C     EPS = DESIRED ACCURACY OF RK4 SOLUTION(1.0E-6)
C     NCR = NUMBER OF CROPS
C --- Other Values
C     ITICK1 = CODE START TIME (SECONDS/100)
C     ITICK2 = CODE END TIME (SECONDS/100)
C     ITICK = CODE EXECUTION TIME (SECONDS)

C INITILIZE AND DEFINE COMMON VARIABLES
      PARAMETER (MAXP = 4,NMAX = 32,NCR = 5,NCUTMAX = 3)
      CHARACTER*8 NUC
      DIMENSION KYEAR(20),NUC(MAXP)
C biomass specific blocks
C CROPPAR.BLK
      COMMON /CROPPAR/TVC,ZKGC,BIC,BMAXC,BSTAND,FD
      DIMENSION TVC(NCR),ZKGC(NCR),BIC(NCR),BMAXC(NCR),FD(NCR),
     !BSTAND(NCR)
C PASTPAR.BLK
      COMMON /PASTPAR/ZKGP,BIP,BMAXP,ZSEN
C HAYPAR.BLK
      COMMON /HAYPAR/ZKGH,BIH,BMAXH,NCUT,TCUT
      DIMENSION TCUT(0:NCUTMAX)
C BEEFPAR.BLK
      COMMON /BEEFPAR/RPB,RHB,RGB,RSB,RLB
C MILKPAR.BLK
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      COMMON /MILKPAR/RPM,RHM,RGM,RSM,RLM
C POULPAR.BLK
      COMMON /POULPAR/RGPL,RSPL,RLPL
C crop and nuclide specific blocks
C CROPNUC.BLK
      COMMON /CROPNUC/CRC,ZKABC
      DIMENSION CRC(NCR,MAXP),ZKABC(NCR,MAXP)
C PASTNUC.BLK
      COMMON /PASTNUC/CRP,ZKABP
      DIMENSION CRP(MAXP),ZKABP(MAXP)
C HAYNUC.BLK
      COMMON /HAYNUC/CRH,ZKABH
      DIMENSION CRH(MAXP),ZKABH(MAXP)
C BEEFNUC.BLK
      COMMON /BEEFNUC/TCB,TCM
      DIMENSION TCB(MAXP),TCM(MAXP)
C POULNUC.BLK
      COMMON /POULNUC/TCPL,TCO
      DIMENSION TCPL(MAXP),TCO(MAXP)
C nuclide specific blocks
C NUCPAR1.BLK
      COMMON /NUCPAR1/NMEMBER,NPROG,THALF,ZKL
      DIMENSION THALF(MAXP),ZKL(MAXP)
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C nuclide and biomass independent parameters
C COMPAR.BLK
      COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
      DIMENSION ALPHA(7)
C state variables blocks
C CROPSTAT.BLK
      COMMON /CROPSTATE/QVSC,QSSC,QRSC,QVIC,QFSC,TQC,QTIC,CTOTAL
      DIMENSION QVSC(NCR,MAXP),QSSC(NCR,MAXP),QRSC(NCR,MAXP)
     !,QVIC(NCR,MAXP),QFSC(NCR,MAXP),TQC(NCR,MAXP),QTIC(NCR,MAXP)
     !,CTOTAL(NCR+2,MAXP)
C PASTSTAT.BLK
      COMMON /PASTSTATE/QVSP,QSSP,QRSP,QVIP,QFSP
      DIMENSION QVSP(MAXP),QSSP(MAXP),QRSP(MAXP),QVIP(MAXP)
     !,QFSP(MAXP)
C HAYSTATE.BLK
      COMMON /HAYSTATE/QVSH,QSSH,QRSH,QVIH,QFSH
      DIMENSION QVSH(MAXP),QSSH(MAXP),QRSH(MAXP),QVIH(MAXP)
     !,QFSH(MAXP)
C BEEFSTAT.BLK
      COMMON /BEEFSTATE/QIBP,QIBH,QIBG,QIBS,QIBT,QIBL,TQB
      DIMENSION QIBP(MAXP),QIBH(MAXP),QIBG(MAXP),QIBS(MAXP),QIBT(MAXP)
     !,QIBL(MAXP),TQB(MAXP)
C MILKSTAT.BLK
      COMMON /MILKSTATE/QIMP,QIMH,QIMG,QIMS,QIMT,QIML,QISM,TQM
      DIMENSION QIMP(MAXP),QIMH(MAXP),QIMG(MAXP),QIMS(MAXP),QIMT(MAXP)
     !,QIML(MAXP),QISM(MAXP),TQM(MAXP)
C POULSTAT.BLK
      COMMON /POULSTATE/QIPLG,QIPLS,QIPLL,QTIPL,TQP
      DIMENSION QIPLG(MAXP),QIPLS(MAXP),QTIPL(MAXP),QIPLL(MAXP),
     !TQP(MAXP)
C OTHERSTA.BLK
      COMMON /OTHERSTATE/QIOG,QIOS,QTIO,QIOP,QIOL,QIOH,TQO
      DIMENSION QIOG(MAXP),QIOS(MAXP),QTIO(MAXP),QIOP(MAXP),QIOH(MAXP),
     !QIOL(MAXP),TQO(MAXP)
C  INPUT PARAMETER DATA AND OPEN OUTPUT FILE
      OPEN(3,FILE='COMIDA.OUT',STATUS='UNKNOWN')
      OPEN(4,FILE='COMIDA.DMP',STATUS='UNKNOWN')
      CALL TIMER(ITICK1)
c     TICK1=SECOND() for INEL cray
      WRITE(3,*) IDKEYW
      CALL INPUTPAR(NTIMES,KYEAR)
C BEGIN LOOP TO CALCULATE
      OPEN(2,FILE='COMIDA.VAR',STATUS='OLD')
C     CREATE LOOP TO INPUT NUCLIDES, CALCULATE CF'S AND STORE RESULTS
      READ(2,*) NNUC
      WRITE(3,1000) NNUC
      WRITE(*,1000) NNUC
      DO 100, I=1,NNUC
        READ(2,*) NUC(1),NPROG,(NUC(K),K=2,NPROG+1)
        READ(2,*) (THALF(K),K=1,NPROG+1)
        NMEMBER=NPROG+1
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      READ(2,*) (ZKL(K),K=1,NMEMBER)
      READ(2,*) ZKAD,ZKDE,NCUTOFF
      WRITE(3,2000) NUC(1),NPROG
      WRITE(4,2000) NUC(1),NPROG
      WRITE(*,2000) NUC(1),NPROG
      CUTOFF=FLOAT(NCUTOFF)*THALF(1)/365
      DO 120,J=1,NMEMBER
        READ(2,*) (CRC(K,J), K=1,NCR)
        READ(2,*) (ZKABC(K,J), K=1,NCR)
        READ(2,*) CRP(J),CRH(J)
        READ(2,*) ZKABP(J),ZKABH(J)
        READ(2,*) TCB(J),TCM(J),TCPL(J),TCO(J)
 120    CONTINUE
      CALL ONEYEAR(NM,NUC,TGROWP,CUTOFF,NCUTOFF)
      K=2
      DO 130,J=2,KYEAR(NTIMES)
        IF(J.EQ.KYEAR(K))THEN
         KFLAG=1
         K=K+1
         ELSE
          KFLAG=0
        ENDIF
      CALL NYEAR(NM,J,KFLAG,NUC,TGROWP,CUTOFF,NCUTOFF)
 130    CONTINUE
C     reset cumulative integrated amounts in the TQi arrays
 132    DO 135,J=1,NCR
        DO 136,K=1,NMEMBER
          TQC(J,K)=0.
 136      CONTINUE
 135    CONTINUE
      DO 138, K=1,NMEMBER
        TQB(K)=0.
        TQM(K)=0.
        TQP(K)=0.
        TQO(K)=0.
 138    CONTINUE
 100 CONTINUE
     CALL TIMER(ITICK2)
C    TICK2=SECOND()
     ITICK=(ITICK2-ITICK1)/100
C     TICK=TICK2-TICK1
     WRITE(3,4000)
     WRITE(3,3000) ITICK
      CLOSE(3,STATUS='KEEP')
      CLOSE(4,STATUS='KEEP')
      CLOSE(5,STATUS='KEEP')
 1000 FORMAT(1X,'NUMBER OF NUCLIDES EVALUATED ',I3)
 2000 FORMAT(24X
    1/,1X,'PARENT NUCLIDE NAME: ',a6,1X,'NUMBER OF PROGENY: ',I2)
 3000 FORMAT(2X,'EXECUTION TIME (seconds) ',I6)
 4000 FORMAT(2X,'+  Cumulative 365 day integrated concentration in food
    1products from the time of the accident.'
    1/2X,'+ +  Animal feed inventories are corrected for hold-up time fro
    1m time of harvest to animal consumption time.'
    1/5X,'Animal product concentrations are corrected for decay of the
    1parent nuclide from production (slaughter)'
    1/5X,'to human consumption.')
      END

C ******************************
C *  SUBROUTINE INPUTPAR       *
C ******************************
     SUBROUTINE INPUTPAR(NTIMES,KYEAR)
     IMPLICIT REAL*8 (A-H,O-Z)
     PARAMETER (MAXP=4,NCR=5,NOA=2,NCUTMAX=3)
C BL=LOWER ACCEPTABLE BOUNDARY LIMIT
C BH=UPPER ACCEPTABLE BOUNDARY LIMIT
C VI=INPUT VALUE
C LNUM=LINE NUMBER IN INPUT DECK
C REC=RECORD NUMBER
*
*    Identification
*    Program Name: COMIDA
*    Module Name: inputpar.f Version 1.8
*    Date: 10/25/93 Time: 10:24:34
*
     Character idkeyw*72
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      Data idkeyw /'@(#)inputpar.f       1.8  10/25/93  10:24:34\0'/
C CROPPAR.BLK
      COMMON /CROPPAR/TVC,ZKGC,BIC,BMAXC,BSTAND,FD
      DIMENSION TVC(NCR),ZKGC(NCR),BIC(NCR),BMAXC(NCR),FD(NCR),
     1BSTAND(NCR)
C PASTPAR.BLK
      COMMON /PASTPAR/ZKGP,BIP,BMAXP,ZSEN
C HAYPAR.BLK
      COMMON /HAYPAR/ZKGH,BIH,BMAXH,NCUT,TCUT
      DIMENSION TCUT(0:NCUTMAX)
C BEEFPAR.BLK
      COMMON /BEEFPAR/RPB,RHB,RGB,RSB,RLB
C MILKPAR.BLK
      COMMON /MILKPAR/RPM,RHM,RGM,RSM,RLM
C POULPAR.BLK
      COMMON /POULPAR/RGPL,RSPL,RLPL
C OTHERPAR.BLK
      COMMON /OTHERPAR/RGO,RSO,RLO,RHHO,RPO
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     1 THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C COMPAR.BLK
      COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
      DIMENSION ALPHA(7)
C PLANT.BLK
      COMMON /PLANT/ ZKG,CR,THICK,RHO,BMAX,BSTART,GTIME
      DIMENSION CR(MAXP)
C MOFIFIER.BLK
      COMMON/MODIFIER/ ATIME,FMOD,NPOINTS
      DIMENSION ATIME(365),FMOD(365)
      DIMENSION KYEAR(20)
      CHARACTER*80 TITLE
      CHARACTER*11 TTIME
      CHARACTER*8 DDATE
      CHARACTER*10 SPC
      CHARACTER*10 FILEIN
      FILEIN='COMIDA.PAR'
      SPC=' — '
      CALL TIME(TTIME)
      CALL DATE(DDATE)
      OPEN(1,FILE='COMIDA.PAR',STATUS='OLD')
      READ(1,*) TITLE
C CROP PARAMETERS

      READ(1,*) (TVC(I),I=1,NCR)
      LNUM=2
      BL=0.0
      BH=1.0
      DO 10,NREC=1,NCR
        VI=TVC(NREC)
        CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
 10   CONTINUE

      READ(1,*) (ZKGC(I),I=1,NCR)
      LNUM=3
      BH=10.0
      DO 20,NREC=1,NCR
        VI=ZKGC(NREC)
        CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
 20   CONTINUE

      READ(1,*) (BIC(I),I=1,NCR)
      LNUM=4
      BL=1.0E-6
      BH=100.0
      DO 30,NREC=1,NCR
        VI=BIC(NREC)
        CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
 30   CONTINUE

      READ(1,*) (BMAXC(I),I=1,NCR)
      LNUM=5
      BL=1.0E-2
      BH=1000.0
      DO 40,NREC=1,NCR
        VI=BMAXC(NREC)
        CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
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40  CONTINUE

    READ(1,*) (BSTAND(I),I=1,NCR)
    LNUM=6
    DO 50,NREC=1,NCR
      VI=BSTAND(NREC)
      CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
50  CONTINUE


    READ(1,*) (FD(I),I=1,NCR)
    LNUM=7
    BL=1E-10
    BH=1.0
    DO 60,NREC=1,NCR
      VI=FD(NREC)
      CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
60  CONTINUE

C PASTURE GRASS PARAMETERS
    READ(1,*) ZKGP,ZSEN
    LNUM=8
    BL=0.0
    BH=10.0
    NREC=1
    CALL CHECK(BL,BH,ZKGP,LNUM,FILEIN,NREC)
    NREC=2
    CALL CHECK(BL,BH,ZSEN,LNUM,FILEIN,NREC)
    READ(1,*) BIP,BMAXP
    LNUM=9
    BL=1.0E-6
    BH=100.0
    NREC=1
    CALL CHECK(BL,BH,BIP,LNUM,FILEIN,NREC)
    NREC=2
    CALL CHECK(BL,BH,BMAXP,LNUM,FILEIN,NREC)
C HAY PARAMETERS
    READ(1,*) ZKGH,BIH,BMAXH
    LNUM=10
    BL=0.0
    BH=10
    NREC=1
    CALL CHECK(BL,BH,ZKGH,LNUM,FILEIN,NREC)
    BL=1.0E-6
    BH=100.
    NREC=2
    CALL CHECK(BL,BH,BIH,LNUM,FILEIN,NREC)
    NREC=3
    CALL CHECK(BL,BH,BMAXH,LNUM,FILEIN,NREC)
    READ(1,*) NCUT,(TCUT(I),I=1,NCUT)
    LNUM=11
    NREC=1
    VI=FLOAT(NCUT)
    BL=1
    BH=3
    CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
    BL=1.0
    BH=365.0
    DO 70,NREC=1,NCUT
      VI=TCUT(NREC)
      CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
70  CONTINUE

C BEEF, MILK, AND OTHER ANIMAL PARAMETERS
    LNUM=12
    NREC=1
    READ(1,*) RPB,RHB,RGB,RSB,RLB
    BL=0.0
    BH=100.0
    CALL CHECK(BL,BH,RPB,LNUM,FILEIN,NREC)
    NREC=NREC+1
    CALL CHECK(BL,BH,RHB,LNUM,FILEIN,NREC)
    NREC=NREC+1
    CALL CHECK(BL,BH,RGB,LNUM,FILEIN,NREC)
    NREC=NREC+1
    CALL CHECK(BL,BH,RSB,LNUM,FILEIN,NREC)
    NREC=NREC+1
```

```
      CALL CHECK(BL,BH,RLB,LNUM,FILEIN,NREC)
      NREC=NREC+1
      READ(1,*) RPM,RHM,RGM,RSM,RLM
      LNUM=13
      NREC=1
      CALL CHECK(BL,BH,RPM,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RHM,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RGM,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RSM,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RLM,LNUM,FILEIN,NREC)
      NREC=NREC+1
      READ(1,*) RGPL,RSPL,RLPL
      LNUM=14
      NREC=1
      CALL CHECK(BL,BH,RGPL,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RSPL,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RLPL,LNUM,FILEIN,NREC)
      READ(1,*) RPO,RHHO,RGO,RSO,RLO
      LNUM=15
      NREC=1
      CALL CHECK(BL,BH,RPO,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RHHO,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RGO,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RSO,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,RLO,LNUM,FILEIN,NREC)
C SOIL AND WEATHERING PARAMETERS
      READ(1,*) ZKP,ZKW,ZKR,ZKRS
      LNUM=16
      NREC=1
      BH=10.
      CALL CHECK(BL,BH,ZKP,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,ZKW,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,ZKR,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,ZKRS,LNUM,FILEIN,NREC)
      READ(1,*) PSS,PSR,XR,XS
      LNUM=17
      NREC=1
      BL=1.0
      BH=1E4
      CALL CHECK(BL,BH,PSS,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,PSR,LNUM,FILEIN,NREC)
      BL=1.0E-6
      BH=100.0
      NREC=1
      CALL CHECK(BL,BH,XR,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,XS,LNUM,FILEIN,NREC)
      READ(1,*) (ALPHA(I),I=1,7)
      LNUM=18
      BL=0.0
      BH=100.0
      DO 80,NREC=1,7
        VI=ALPHA(NREC)
        CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
   80 CONTINUE

C TIME PARAMETERS
      READ(1,*) TINTM,TT,TSC,TSP,TSL
      READ(1,*) TSH,TEC,TEL,TI

      LNUM=19
      NREC=1
      BL=1.
```

```
      BH=TEL-TSL
      CALL CHECK(BL,BH,TINTM,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,TT,LNUM,FILEIN,NREC)
      NREC=NREC+1
      BH=200.
      CALL CHECK(BL,BH,TSC,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,TSL,LNUM,FILEIN,NREC)

      NREC=1
      LNUM=20
      CALL CHECK(BL,BH,TSH,LNUM,FILEIN,NREC)
      NREC=NREC+1
      BH=365.
      CALL CHECK(BL,BH,TEC,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,TEL,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,TI,LNUM,FILEIN,NREC)
C     check time parameters for overlap
      CALL TIMECK

      BL=0.
      READ(1,*) THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
      NREC=1
      LNUM=21
      CALL CHECK(BL,BH,THBEEF,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,THMILK,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,THPOL,LNUM,FILEIN,NREC)
      NREC=NREC+1
      CALL CHECK(BL,BH,THOTHER,LNUM,FILEIN,NREC)
      NREC=NREC+1
      BH=365-TEC
      CALL CHECK(BL,BH,THGL,LNUM,FILEIN,NREC)
      NREC=NREC+1
      BH=365-TCUT(NCUT)
      CALL CHECK(BL,BH,THHAY,LNUM,FILEIN,NREC)

      READ(1,*) NTIMES,(KYEAR(I),I=1,NTIMES)
      LNUM=22
      BL=1
      BH=500
      NREC=1
      VI=FLOAT(NTIMES)
      CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
      IF(KYEAR(1).NE.1)THEN
        WRITE(*,*) 'ERROR: FIRST VALUE OF KYEAR MUST BE 1'
        PAUSE
      ENDIF
      BH=1E6
      DO 90, NREC=2,NTIMES
       IF(KYEAR(NREC).LE.KYEAR(NREC-1))THEN
         WRITE(*,*) 'ERROR: KYEAR VALUES MUST BE IN ASSENDING ORDER'
         PAUSE
       ENDIF
       VI=FLOAT(KYEAR(NREC))
       CALL CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
   90 CONTINUE

      CLOSE(1,STATUS='KEEP')
      WRITE(3,*) IDKEYW
      WRITE(3,*) 'TIME: ',TTIME
      WRITE(3,*) 'DATE: ',DDATE
      WRITE(3,*) 'TITLE: ',TITLE
      WRITE(3,100)
      WRITE(*,100)
      WRITE(*,200)
      WRITE(*,250)
      WRITE(3,200)
      WRITE(3,250)
      WRITE(*,*) TITLE
      WRITE(3,300) (ALPHA(I),I=1,5),(TVC(I),I=1,NCR),(ZKGC(I),I=1,NCR),
     1(BIC(I),I=1,NCR),(BMAXC(I),I=1,NCR),(BSTAND(I),I=1,NCR),
     1(FD(I),I=1,NCR)
```

```
      WRITE(3,400) SPC,SPC,ZKGH,ZKGP,SPC,
     ! SPC,SPC,BIH,BIP,SPC,
     ! SPC,SPC,BMAXH,BMAXP,SPC,
     ! SPC,SPC,ALPHA(6),ALPHA(7),SPC,
     ! SPC,SPC,SPC,ZSEN,SPC,
     ! RGB,RLB,RHB,RPB,RSB,
     ! RGM,RLM,RHM,RPM,RSM,
     ! RGPL,RLPL,SPC,SPC,RSPL,
     ! RGO,RLO,RHHO,RPO,RSO

      WRITE(3,500) NCUT,(TCUT(I),I=1,NCUT),TINTM
      WRITE(3,600) ZKP,ZKW,ZKR,ZKRS,PSS,PSR,XR,XS
      WRITE(3,700) TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,THBEEF,THMILK,
     !THPOL,THOTHER,THGL,THHAY

100  FORMAT(2X,' ******************* COMIDA *********************'
     !/,2X,' * A dynamic food chain model for use in the MACCS *'
     !/,2X,' *        reactor consequence code.              *'
     !/,2X ' *     Arthur S. Rood and Michael L. Abbott       *'
     !/,2X,' *    Idaho National Engineering Laboratory       *'
     !/,2X,' *    EG&G Idaho PO Box 1625 Idaho Falls          *'
     !/,2X,' *                ID 83401.                       *'
     !/,2X,' *          Version Control Copy                  *'
     !/,2X,' *       Version 1.01  October 25, 1993           *'
     !/,2X,' ************************************************')


200 FORMAT(2X,'-----------------------------------------------------
     !---------------------'
     !/9x,' ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND'
     !/9x,'        LIMITATION OF LIABILITY '
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     !oduct or process'
     !/2x,'disclosed, or represents that its use would not infringe on p
     !rivately owned')

250 FORMAT(2x,'rights. Subroutines RK4, RKQC and ODEINT are Copyright
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     !/,2x,'Recipes Software. Reproduced by permission from the book, N
     !umerical'
     !,/2x,'Recipes, Cambridge University Press.'
     !/,2x,'-----------------------------------------------------
     !---------------'
     !/2x,'                                   ')

300 FORMAT(1X,'          PARAMETER VALUES FOR COMIDA'
     /,1X
     !/,1X,'---- CROP VALUES ----                    LEAFY
     ! ROOT'
     !/,1X,'                               GRAINS  VEGETABLES
     ! CROPS    FRUITS   LEGUMES'
     !/,1X,'                               ______________
     !_______________________'
     !/,1X,'INTERCEPTION FRAC (m**2/kg):         ',1PE9.2,1X,1PE9.2,1
     !X,1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,1X,'FRACTION TO EDIBLE PORTION OF CROP:   ',1PE9.2,1X,1PE9.2,1
     !X,1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,1X,'GROWTH RATE CONSTANT (d-1):          ',1PE9.2,1X,1PE9.2,1
     !X,1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,1X,'INITIAL CROP BIOMASS (kg(dry)/m**2):  ',1PE9.2,1X,1PE9.2,1
     !X,1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,1X,'MAXIMUM CROP BIOMASS (kg(dry)/m**2):  ',1PE9.2,1X,1PE9.2,1
     !X,1PE9.2,1X,1PE9.2,1X,1PE9.2
     !/,1X,'STANDING CROP BIOMASS (kg(dry)/m**2): ',1PE9.2,1X,1PE9.2,1
     !X,1PE9.2,1X,1PE9.2,1X,1PE9.2
```

```
 !/,1X,'DRY WEIGHT TO WET WEIGHT RATIO:        ',1PE9.2,1X,1PE9.2,1
 !X,1PE9.2,1X,1PE9.2,1X,1PE9.2)

400 FORMAT(1X,
 !/,1X,'---- ANIMAL FEED PARAMETERS ----     GRAINS  LEGUMES
 ! HAY     PASTURE*  SOIL  '
 !/,1X,'                                  _____________
 !_______________________'
 !/,1X,'GROWTH RATE CONSTANT (d**-1):        ',a10     ,a10
 !,1PE9.2,1X,1PE9.2,a10
 !/,1X,'INITIAL CROP BIOMASS (kg(dry)/m**2):  ',a10  ,a10
 !,1PE9.2,1X,1PE9.2,a10
 !/,1X,'MAXIMUM CROP BIOMASS (kg(dry)/m**2):  ',a10    ,a10
 !,1PE9.2,1X,1PE9.2,a10
 !/,1X,'FOLIAR INTERCEPTION FRAC (m**2/kg):   ',a10     ,a10
 !,1PE9.2,1X,1PE9.2,a10
 !/,1X,'SENESCENCE RATE CONSTANT (d-1):       ',a10  ,a10  ,a10
 ! ,1X,1PE9.2,a10
 !/,1X,'ANNUAL AVG BEEF COW CONSUMPTION (kg/d): ',1PE9.2,1X,1PE9.2,1
 !X,1PE9.2,1X,1PE9.2,1X,1PE9.2
 !/,1X,'ANNUAL AVG MILK COW CONSUMPTION (kg/d): ',1PE9.2,1X,1PE9.2,1
 !X,1PE9.2,1X,1PE9.2,1X,1PE9.2
 !/,1X,'ANNUAL AVG POULTRY CONSUMPTION (kg/d):  ',1PE9.2,1x,1PE9.2,a10
 ! ,a10    ,1X,1PE9.2
 !/,1X,'ANNUAL AVG OTHER ANIMAL CONSUMP (kg/d): ',1PE9.2,1X,1PE9.2,1
 !X,1PE9.2,1X,1PE9.2,1X,1PE9.2
 !/,' * ingestion rate only while animal is on pasture'
 !/,10X)

500 FORMAT(1X'---- OTHER FEED PARAMETERS ----'
 !/,1X,'NUMBER OF HAY CUTTINGS:              ',I2
 !/,1X,'HAY CUTTING TIMES (JULIAN DAY):          ',F4.0,1X,F4.
 !0,1X,F4.0
 !/,1X,'SHORT TERM PASTURE INT. TIME FOR MILK (d):   ',1PE9.2
 !,10X
 !/,' ')

600 FORMAT(1X,'---- SOIL PARAMETERS ----'
 !/,1X,'PERCOLATION RATE CONSTANT (d**-1):          ',1PE9.2
 !/,1X,'WEATHERING RATE CONSTANT (d**-1):           ',1PE9.2
 !/,1X,'RESUSPENTION RATE CONSTANT (d**-1):         ',1PE9.2
 !/,1X,'RAINSPLASH RATE CONSTANT (d**-1):          ',1PE9.2
 !/,1X,'SURFACE SOIL DENSITY (kg/m**3):          ',1PE9.2
 !/,1X,'ROOT SOIL DENSITY (kg/m**3):             ',1PE9.2
 !/,1X,'DEPTH OF ROOTING ZONE (m):               ',1PE9.2
 !/,1X,'SURFACE SOIL COMPARTMENT THICKNESS (m):      ',1PE9.2
 !/,10X)

700 FORMAT(1X,'---- TIME PARAMETERS ----'
 !/,1X,'TIME OF TILLAGE (JULIAN DAY):             ',F4.0
 !/,1X,'START OF CROP GROWING SEASON (JULIAN DAY):    ',F4.0
 !/,1X,'START OF PASTURE GROWING SEASON (JULIAN DAY): ',F4.0
 !/,1X,'START OF GRAZING SEASON (JULIAN DAY):         ',F4.0
 !/,1X,'START OF HAY GROWING SEASON (JULIAN DAY):     ',F4.0
 !/,1X,'END OF CROP GROWING SEASON (JULIAN DAY):      ',F4.0
 !/,1X,'END OF GRAZING SEASON (JULIAN DAY):          ',F4.0
 !/,1X,'TIME OF FALLOUT EVENT (JULIAN DAY):          ',F4.0
 !/,1X,'HOLD-UP TIME, BEEF (DAYS):                  ',F4.0
 !/,1X,'HOLD-UP TIME, MILK (DAYS):                  ',F4.0
 !/,1X,'HOLD-UP TIME, POULTRY (DAYS):                ',F4.0
 !/,1X,'HOLD-UP TIME, OTHER ANIMAL (DAYS):           ',F4.0
 !/,1X,'HOLD-UP TIME, ANIMAL FEED GRAIN&LEGUME (DAYS): ',F4.0
 !/,1X,'HOLD-UP TIME, ANIMAL FEED HAY (DAYS):         ',F4.0
 !/,1X,' '
 !/,1X,'UNITS: CROP CONCENTRATION:      Bq/kg (wet weight)'
 !/,1X,'      ANIMAL FEED COMPARTMENTS: Bq/m**2 (dry weight)'
 !/,1X,'      SOIL COMPARTMENTS:       Bq/m**2   '
 !/,1X,'      MILK: Bq-d/L '
 !/,1X,'      MEAT: Bq-d/kg')

999 RETURN
    END

C ******************************
C * SUBROUTINE CHECK       *
C ******************************
    SUBROUTINE CHECK(BL,BH,VI,LNUM,FILEIN,NREC)
```

```
      IMPLICIT REAL*8 (A-H,O-Z)
C This subroutine checks values read in INPUTPAR and MAIN for reasonable
C bounding limits.  Called by INPUTPAR and MAIN
      CHARACTER*10 FILEIN
*
*     Identification
*     Program Name: COMIDA
*     Module Name: check.f Version 1.2
*     Date: 1/19/93 Time: 10:01:53
*
      Character idkeyw*72
      Data idkeyw /'@(#)check.f        1.2 1/19/93 10:01:53\0'/
      idkeyw = idkeyw
      IF(VI.GE.BL.AND.VI.LE.BH)THEN
       RETURN
       ELSE
        WRITE(*,100) LNUM,NREC,FILEIN,VI,BH,BL
        PAUSE
      ENDIF
  100 FORMAT(1X,'ERROR: IN LINE NUMBER ',I3,' RECORD ',I2,' IN ',a10
     !/,1X,'VALUE OUT OF ACCEPTED BOUNDS'
     !/,1X,'INPUT VALUE: ',1PE11.4
     !/,1X,'ACCEPTED UPPER VALUE: ',1PE11.4
     !/,1X,'ACCEPTED LOWER VALUE: ',1PE11.4)
                              RETURN
      END
C ******************************
C *  SUBROUTINE TIMECK         *
C ******************************
      SUBROUTINE TIMECK
      IMPLICIT REAL*8 (A-H,O-Z)
C This subroutine checks the time variables read in INPUTPAR and assures
C that the begin times are before the end times for crops and livestock
C and that the time of accident does not occur on the same day of the start
C or end of a growing season.  Called by INPUTPAR
*
*     Identification
*     Program Name: COMIDA
*     Module Name: timeck.f Version 1.3
*     Date: 1/19/93 Time: 11:22:17
*
       INCLUDE 'TIMEPAR.BLK'
      Character idkeyw*72
      Data idkeyw /'@(#)timeck.f        1.3 1/19/93 11:22:17\0'/
      idkeyw = idkeyw

      IF(TSC.GE.TEC)THEN
        WRITE(*,*) 'ERROR: TSC CANNOT BE GREATER THAN TEC IN LINE 19 &
     ! 20'
        PAUSE
      ENDIF
      IF(TSL.GE.TEL)THEN
        WRITE(*,*) 'ERROR: TSL CANNOT BE GREATER THAN TEL IN LINE 19 &
     ! 20'
        PAUSE
      ENDIF
      IF(TSP.GE.TEL)THEN
        WRITE(*,*) 'ERROR: TSP CANNOT BE GREATER THAN TEL IN LINE 19 &
     ! 20'
        PAUSE
      ENDIF
      IF(TSL.GE.TEL)THEN
        WRITE(*,*) 'ERROR: TSL CANNOT BE GREATER THAN TEL IN LINE 19 &
     ! 20'
        PAUSE
      ENDIF

      RETURN
      END

C ******************************
C *  SUBROUTINE CROP1          *
C ******************************
      SUBROUTINE CROP1(TGROW,NM,QTIG,QTIL,T1)
C     This subroutine calculates the concentration in crops for the year
C     the accident occurred.
      IMPLICIT REAL*8 (A-H,O-Z)
```

```
*
*   Identification
*   Program Name: COMIDA
*   Module Name: crop1.f Version 1.2
*   Date: 1/19/93 Time: 10:19:36
*
C   NRDK = NUMBER OF COMPARTMENTS TO BE PASSED TO SUBROUTINE RDK
C   GTIME = TIME ELASPED FROM START OF GROWING SEASON
C   FVC(I) = FALLOUT FRACTION TO CROP SURFACE
C   FSC(I) = FALLOUT FRACTION TO CROP SOIL SURFACE
C   QTIG(J) = INTEGRATED ANIMAL GRAIN INVENTORY
C   QTIL(J) = INTEGRATED ANIMAL LEGUME INVENTORY
C   dummy values are given to BMAX and BSTART to avoid divsion by
C   zero in DERIVS
C   NM = NUMBER OF MEMBERS IN DECAY CHAIN
C   T1G,T1L = ANIMAL FEED INTEGRATION TIMES FOR GRAIN AND LEGUME
     PARAMETER (MAXP = 4,NMAX = 32,NCR = 5)
C CROPPAR.BLK
      COMMON /CROPPAR/TVC,ZKGC,BIC,BMAXC,BSTAND,FD
      DIMENSION TVC(NCR),ZKGC(NCR),BIC(NCR),BMAXC(NCR),FD(NCR),
     !BSTAND(NCR)
C CROPNUC.BLK
      COMMON /CROPNUC/CRC,ZKABC
      DIMENSION CRC(NCR,MAXP),ZKABC(NCR,MAXP)
C CROPSTAT.BLK
      COMMON /CROPSTATE/QVSC,QSSC,QRSC,QVIC,QFSC,TQC,QTIC,CTOTAL
      DIMENSION QVSC(NCR,MAXP),QSSC(NCR,MAXP),QRSC(NCR,MAXP)
     !,QVIC(NCR,MAXP),QFSC(NCR,MAXP),TQC(NCR,MAXP),QTIC(NCR,MAXP)
     !,CTOTAL(NCR + 2,MAXP)
C COMPAR.BLK
      COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
      DIMENSION ALPHA(7)
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C PLANT.BLK
      COMMON /PLANT/ ZKG,CR,THICK,RHO,BMAX,BSTART,GTIME
      DIMENSION CR(MAXP)
C ANIMALF.BLK
      COMMON /ANIMALF/ PGRAIN,PLEGUME,PHAY
      DIMENSION PGRAIN(MAXP),PLEGUME(MAXP),PHAY(MAXP)
      COMMON /RCONTANTS/ Z12,Z15,Z21,Z23,Z34,Z3,Z43,D,Z52
      DIMENSION A(NMAX),D(MAXP),Z3(MAXP),Z15(MAXP)
      DIMENSION QTIG(MAXP),QTIL(MAXP),DX(MAXP + 1)
      Character idkeyw*72
      Data idkeyw /'@(#)crop1.f          1.2  1/19/93  10:19:36\0'/
      idkeyw = idkeyw
      WRITE(*,*) 'CALCULATING FIRST CALENDER YEAR CROP INVENTORIES '
C   Set minimum and maximum biomass to dummy values. Set julian day counter
C   to day of accident
      BMAX = 1.0
      BSTART = 0.1
C   set senescence rate constant to zero
      Z52 = 0.0
C   ****************************************************************
C   check TGROW to see if accident occurred during growing season (TGROW>0)
      IF(TGROW.GT.0.)THEN
C   accidient occurred during growing season,
        X1 = 0.0
        X2 = TGROW
        Z12 = ZKW
        Z21 = ZKR + ZKRS
        DO 20,I = 1,NCR
C         initialize state variables
          DO 40,J = 1,NMAX
            A(J) = 0.0
 40       CONTINUE
          ZKG = ZKGC(I)
          BMAX = BMAXC(I)
          BSTART = BIC(I)
          BSND = BSTAND(I)
          ALPHAX = ALPHA(I)
C         calculate time elasped in growing season
          GTIME = TI-TSC
C         calculate fraction of fallout to veg surface and soil surface
          WRITE(4,*) 'CURRENT BIOMASS, FVC AND FVS VALUES FOR CROP ',I
          CALL FALLOUT(FVC,FSC,BSTART,BSND,GTIME,ZKG,ALPHAX)
```

```
        A(1) = FVC
        A(2) = FSC
C       set concentration ratio value
        DO 60,J = 1,NM
          CR(J) = CRC(I,J)
          Z15(J) = ZKABC(I,J)
60      CONTINUE
        CALL RK4SOLVE(A,X1,X2,NM)
C       save results in state variable matrix, convert to wet weight
C       and fraction deposited to ediable portion
        DO 80,J = 1,NM
          K = (J-1)*8
          QVSC(I,J) = A(1 + K)*FD(I)*TVC(I)/BMAXC(I)
          QSSC(I,J) = A(2 + K)
          QRSC(I,J) = A(3 + K)
          QFSC(I,J) = A(4 + K)
          QVIC(I,J) = A(5 + K)*FD(I)/BMAXC(I)
80      CONTINUE
20    CONTINUE

    ENDIF
C   ************************************************************
C   check TGROW for accident occurance befor or after growing season.
    IF(TGROW.LT.0.0.AND.TI.LT.TSC)THEN
C     initialize state variables
      DO 90,J = 1,NMAX
        A(J) = 0.0
90    CONTINUE
C     run model to start of growing season setting weathering, resuspention
C     rainsplash and root uptake rate constants to zero. Inital and
C     max biomass were set to dummy values of 0.1 and 1.0 at start of routine
C     All Initial fallout assumed to go to soil.

      A(2) = 1.0
      Z12 = 0.0
      Z21 = 0.0
      ZKG = 0.0
      X1 = 0.0
      X2 = TSC-TI
C     Solve those guys !!!!!!!!!!!!!!!
      CALL RK4SOLVE(A,X1,X2,NM)
C     did accident occur befor tillage ?? If so then distribute activity
C     evenly between surface soil (SURF) and root zone (ROOTZ) soil compartment.
C     D1 and D2 are dummy variables that pass the inital values in the surface
C     soil and labile soil to the subroutine TILL.  The redistributed activity
C     is returned in the variables SURF and ROOTZ.
      IF(TI.LT.TT)THEN
        D1 = A(2)
        D2 = A(3)
        CALL TILL(SURF,ROOTZ,D1,D2)
        A(2) = SURF
        A(3) = ROOTZ
      ENDIF
C     now calculate concentrations for each food type given initial soil
C     inventories in compartments  A(2), A(3) AND A(4). GTIME is set to
C     zero since none of the growing season has elasped.
      X1 = 0.0
      X2 = TEC-TSC
      GTIME = 0.0
      DO 110,I = 1,NCR
        DO 115,J = 1,NM
          QSSC(I,J) = A(2 + (J-1)*8)
          QRSC(I,J) = A(3 + (J-1)*8)
          QFSC(I,J) = A(4 + (J-1)*8)
115     CONTINUE
110   CONTINUE
C     reset resuspention,weathering  and rainsplash rate constants
      Z21 = ZKRS + ZKR
      Z12 = ZKW
C     initialize activity array
      DO 118, I = 1,NMAX
        A(I) = 0.0
118   CONTINUE
      DO 120,I = 1,NCR
        ZKG = ZKGC(I)
        BMAX = BMAXC(I)
        BSTART = BIC(I)
```

```
C        set concentration ratio values and parent and progeny soil inventories
         DO 130,J=1,NM
           CR(J)=CRC(I,J)
           Z15(J)=ZKABC(I,J)
           A(2+(J-1)*8)=QSSC(I,J)
           A(3+(J-1)*8)=QRSC(I,J)
           A(4+(J-1)*8)=QFSC(I,J)
 130       CONTINUE
C         Solve those guys !!!!!!!!!
         CALL RK4SOLVE(A,X1,X2,NM)
C        save results in state variable matrix, convert to wet weight
C        activity per kg and account for washing
         DO 140,J=1,NM
           QVSC(I,J)=A(1+(J-1)*8)*FD(I)*TVC(I)/BMAXC(I)
           QSSC(I,J)=A(2+(J-1)*8)
           QRSC(I,J)=A(3+(J-1)*8)
           QFSC(I,J)=A(4+(J-1)*8)
           QVIC(I,J)=A(5+(J-1)*8)*FD(I)/BMAXC(I)
 140       CONTINUE
 120     CONTINUE
     ENDIF
C    *******************************************************************
C    check if accident occured after growing season (TI>TEC)
     IF(TI.GE.TEC)THEN
C    put entire inventory in surface soil compartment and calculate TEND
C    which is the time to start of next growing season
       DO 150,I=1,NCR
         QSSC(I,1)=1.0
 150     CONTINUE
       TEND=365-TI + TSC
       ELSE
        TEND=365-TEC+TSC
C + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
C        calculate total integrated activity in crops for 1 year
C        For animal feed totals (CTOTAL (6,J) and CTOTAL(7,J)), activity is
C        converted back to dry weight and not corrected for translocation
        DO 155,J=1,NM
          CTOTAL(6,J)=QVSC(1,J)/(FD(1)*TVC(1))+QVIC(1,J)/FD(1)
          CTOTAL(7,J)=QVSC(5,J)/(FD(5)*TVC(5))+QVIC(5,J)/FD(5)
          DX(J)=D(J)
 155      CONTINUE
        DO 160,I=1,NCR
         DO 165,J=1,NM
           CTOTAL(I,J)=QVSC(I,J)+QVIC(I,J)
 165       CONTINUE
 160      CONTINUE
        CALL FEEDI(T1,T2,QTIG,QTIL,NM,DX)
        WRITE(4,1000) (QTIG(J),J=1,MAXP)
        WRITE(4,2000) (QTIL(J),J=1,MAXP)
     ENDIF
C    *******************************************************************
C    Calculate concentrations in soil comaprtments to next growing season for all
C    cases.  Set rainsplash and root uptake rate constants to zero
     Z12=0.0
     Z21=0.0
     ZKG=0.0
     X1=0.0
     X2=TEND
C    now calculate concentration in soil compartments to beginning of next growing
C    season and save in crop state variable matrix.  First, reset activity matrix.
     DO 210,I=1,NMAX
       A(I)=0.0
 210 CONTINUE
C    begin loop to calculate soil concentrations at end of year
     DO 220, I=1,NCR
C    set initial inventories
       DO 230,J=1,NM
         A(2+(J-1)*8)=QSSC(I,J)
         A(3+(J-1)*8)=QRSC(I,J)
         A(4+(J-1)*8)=QFSC(I,J)
 230     CONTINUE
       CALL RK4SOLVE(A,X1,X2,NM)
C      save results in state variable matrix
       DO 240,J=1,NM
         QSSC(I,J)=A(2+(J-1)*8)
         QRSC(I,J)=A(3+(J-1)*8)
         QFSC(I,J)=A(4+(J-1)*8)
```

```
240    CONTINUE
220  CONTINUE

1000 FORMAT(1X,'INTEGRATED ANIMAL FEED (QTIG) GRAIN ACTIVITIES'
   I/,1X,'QTIG(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2)
2000 FORMAT(1X,'INTEGRATED ANIMAL FEED (QTIL) LEGUME ACTIVITIES'
   I/,1X,'QTIL(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2)
     RETURN
     END
C ******************************
C *  SUBROUTINE CROPN         *
C ******************************
C This subroutine calculates concentrations in crops for N years periode
C after accident.
     SUBROUTINE CROPN(NM,QTIG,QTIL,T1,T2)
     IMPLICIT REAL*8 (A-H,O-Z)
C    GTIME=time elasped of growing season, set equal to zero since no time has
C    elasped.
C    NM = number of members in decay chain
C    NRDK=NUMBER OF COMPARTMENTS TO PASS TO THE RDK SUBROUTINE
C    QTG(J)=TOTAL ANIMAL GRAIN INVENTORY
C    QTIG(J)=INTEGRATED ANIMAL GRAIN INVENTORY
C    QTL(J)=TOTAL ANIMAL LEGUME INVENTORY
C    QTIL(J)=INTEGRATED ANIMAL LEGUME INVENTORY
     PARAMETER (MAXP=4,NMAX=32,NCR=5)
*
*    Identification
*    Program Name: COMIDA
*    Module Name: cropn.f Version 1.2
*    Date: 1/19/93 Time: 10:21:15
*
C CROPPAR.BLK
     COMMON /CROPPAR/TVC,ZKGC,BIC,BMAXC,BSTAND,FD
     DIMENSION TVC(NCR),ZKGC(NCR),BIC(NCR),BMAXC(NCR),FD(NCR),
    IBSTAND(NCR)
C CROPNUC.BLK
     COMMON /CROPNUC/CRC,ZKABC
     DIMENSION CRC(NCR,MAXP),ZKABC(NCR,MAXP)
C CROPSTAT.BLK
     COMMON /CROPSTATE/QVSC,QSSC,QRSC,QVIC,QFSC,TQC,QTIC,CTOTAL
     DIMENSION QVSC(NCR,MAXP),QSSC(NCR,MAXP),QRSC(NCR,MAXP)
    I,QVIC(NCR,MAXP),QFSC(NCR,MAXP),TQC(NCR,MAXP),QTIC(NCR,MAXP)
    I,CTOTAL(NCR+2,MAXP)
C COMPAR.BLK
     COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
     DIMENSION ALPHA(7)
C TIMEPAR.BLK
     COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
    I THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C PLANT.BLK
     COMMON /PLANT/ ZKG,CR,THICK,RHO,BMAX,BSTART,GTIME
     DIMENSION CR(MAXP)
     COMMON /RCONTANTS/ Z12,Z15,Z21,Z23,Z34,Z3,Z43,D,Z52
     DIMENSION A(NMAX),D(MAXP),Z3(MAXP),Z15(MAXP)
     DIMENSION QTIG(MAXP),QTIL(MAXP),DX(MAXP+1)
     Character idkeyw*72
     Data idkeyw /'@(#)cropn.f       1.2  1/19/93  10:21:15\0'/
     idkeyw=idkeyw
     WRITE(*,*) 'CALCULATING nTH CALENDER YEAR CROP'
C set senescence rate constant to zero
       Z52=0.0
       GTIME=0.0
C      initialize state variables
      DO 10,J=1,NMAX
        A(J)=0.0
 10    CONTINUE

C Redistribution from tillage is performed befor the start of growing season.
     DO 20, I=1,NCR
       DO 30,J=1,NM
         D1=QSSC(I,J)
         D2=QRSC(I,J)
         CALL TILL(SURF,ROOTZ,D1,D2)
         QSSC(I,J)=SURF
         QRSC(I,J)=ROOTZ
 30      CONTINUE
 20    CONTINUE
```

```
C Now calculate concentrations for each food type given initial soil
C inventories in compartments  A(2), A(3) AND A(4).
C Reset resuspention weathering and rainsplash rate constants
    Z21 = ZKRS + ZKR
    Z12 = ZKW
    X1 = 0.0
    X2 = TEC-TSC
    DO 40,I = 1,NCR
        ZKG = ZKGC(I)
        BMAX = BMAXC(I)
        BSTART = BIC(I)
C         set concentration ratio values and absorption for parent and
C         progeny inventories
        DO 50,J = 1,NM
          CR(J) = CRC(I,J)
          Z15(J) = ZKABC(I,J)
          A(2 + (J-1)*8) = QSSC(I,J)
          A(3 + (J-1)*8) = QRSC(I,J)
          A(4 + (J-1)*8) = QFSC(I,J)
C           reset crop internal inventories to zero CORRECTION MADE 10/27/92
          A(5 + (J-1)*8) = 0.0
 50       CONTINUE
C         Solve those guys !!!!!!!!!
        CALL RK4SOLVE(A,X1,X2,NM)
C         save results in state variable matrix, convert to wet weight
C         activity per kg and account for washing
        DO 60,J = 1,NM
          QVSC(I,J) = A(1 + (J-1)*8)*FD(I)*TVC(I)/BMAXC(I)
          QSSC(I,J) = A(2 + (J-1)*8)
          QRSC(I,J) = A(3 + (J-1)*8)
          QFSC(I,J) = A(4 + (J-1)*8)
          QVIC(I,J) = A(5 + (J-1)*8)*FD(I)/BMAXC(I)
 60       CONTINUE
 40   CONTINUE
C +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
C   calculate total integrated activity in each crop type begin with animal
C   grain and legume feed that are converted back to dry weight and not
C   corrected for translocation
    DO 155,J = 1,NM
        CTOTAL(6,J) = QVSC(1,J)/(FD(1)*TVC(1)) + QVIC(1,J)/FD(1)
        CTOTAL(7,J) = QVSC(5,J)/(FD(5)*TVC(5)) + QVIC(5,J)/FD(5)
        DX(J) = D(J)
 155 CONTINUE
    DO 160,I = 1,NCR
      DO 165,J = 1,NM
        CTOTAL(I,J) = QVSC(I,J) + QVIC(I,J)
 165    CONTINUE
 160 CONTINUE
    CALL FEEDI(T1,T2,QTIG,QTIL,NM,DX)
    WRITE(4,1000) (QTIG(J),J = 1,MAXP)
    WRITE(4,2000) (QTIL(J),J = 1,MAXP)
C +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
C   Calculate concentrations in soil compartments to end of year.
C   Set rainsplash and root uptake rate constants to zero for
C   calculation to end of year.
    Z12 = 0.0
    Z21 = 0.0
    ZKG = 0.0
    X1 = 0.0
    X2 = 365 - TEC + TSC
C   now calculate concentration in soil compartments to end of year and
C   save in crop state variable matrix.  First, reset activity matrix.
    DO 210,I = 1,NMAX
      A(I) = 0.0
 210 CONTINUE
C   begin loop to calculate soil concentrations at end of year
    DO 220, I = 1,NCR
C   set initial inventories
      DO 230,J = 1,NM
        A(2 + (J-1)*8) = QSSC(I,J)
        A(3 + (J-1)*8) = QRSC(I,J)
        A(4 + (J-1)*8) = QFSC(I,J)
 230  CONTINUE
      CALL RK4SOLVE(A,X1,X2,NM)
C     save results in state variable matrix
      DO 240,J = 1,NM
        QSSC(I,J) = A(2 + (J-1)*8)
```

```
        QRSC(I,J) = A(3 + (J-1)*8)
        QFSC(I,J) = A(4 + (J-1)*8)
 240    CONTINUE
 220  CONTINUE

 1000 FORMAT(1X,'INTEGRATED ANIMAL FEED (QTIG) GRAIN ACTIVITIES'
     !/,1X,'QTIG(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2)

 2000 FORMAT(1X,'INTEGRATED ANIMAL FEED (QTIL) LEGUME ACTIVITIES'
     !/,1X,'QTIL(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2)
      RETURN
      END

C *****************************
C *  SUBROUTINE TILL        *
C *****************************
      SUBROUTINE TILL(SURF,ROOT,D1,D2)
      IMPLICIT REAL*8 (A-H,O-Z)
C this subroutine redistibutes activity in the soil compartments after
C tillage.
C ZMS = TOTAL MASS IN SURFACE SOIL COMAPRTMENT (kg)
C ZMR = TOTAL MASS IN ROOT SOIL COMPARTMENT (kg)
C SR = SURFACE SOIL RATIO
C RR = ROOT SOIL RATIO
C T = TOTAL ACTIVITY
C D1 = INITIAL ACTIVITY IN SURFACE SOIL
C D2 = INITIAL ACTIVITY IN ROOT SOIL
*
*     Identification
*     Program Name: COMIDA
*     Module Name: till.f Version 1.2
*     Date: 1/19/93 Time: 10:22:05
*
C COMPAR.BLK
      COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
      DIMENSION ALPHA(7)
      Character idkeyw*72
      Data idkeyw /'@(#)till.f          1.2 1/19/93 10:22:05\0'/
      idkeyw = idkeyw
C CALCULATE TOTAL MASS IN EACH SOIL COMPARTMENT
      ZMS = XS*PSS
      ZMR = XS*PSR
C CALCULATE MASS SOIL RATIOS
      SR = ZMS/(ZMS + ZMR)
      RR = ZMR/(ZMS + ZMR)
      T = D1 + D2
      SURF = SR*T
      ROOT = RR*T
      RETURN
      END
C *****************************
C *  SUBROUTINE FEEDI       *
C *****************************
      SUBROUTINE FEEDI(T1,T2,QTIG,QTIL,NM,DX)
C     This subroutine calculates the integrated animal feed concentrations
C     for the current years crops
      IMPLICIT REAL*8 (A-H,O-Z)
C     NRDK = NUMBER OF COMPARTMENTS TO BE PASSED TO SUBROUTINE RDK
C     QTIG(J) = INTEGRATED ANIMAL GRAIN INVENTORY
C     QTIL(J) = INTEGRATED ANIMAL LEGUME INVENTORY
      PARAMETER (MAXP = 4,NCR = 5)
*
*     Identification
*     Program Name: COMIDA
*     Module Name: feedi.f Version 1.2
*     Date: 1/19/93 Time: 10:23:00
*
C CROPSTAT.BLK
      COMMON /CROPSTATE/QVSC,QSSC,QRSC,QVIC,QFSC,TQC,QTIC,CTOTAL
      DIMENSION QVSC(NCR,MAXP),QSSC(NCR,MAXP),QRSC(NCR,MAXP)
     !,QVIC(NCR,MAXP),QFSC(NCR,MAXP),TQC(NCR,MAXP),QTIC(NCR,MAXP)
     !,CTOTAL(NCR + 2,MAXP)
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C ANIMALF.BLK
      COMMON /ANIMALF/ PGRAIN,PLEGUME,PHAY
```

```
      DIMENSION PGRAIN(MAXP),PLEGUME(MAXP),PHAY(MAXP)
      DIMENSION Q(MAXP+1),QDX(MAXP+1),QIX(MAXP+1),DX(MAXP+1),
     1TGRAIN(MAXP),TLEGUME(MAXP),QTIL(MAXP),QTIG(MAXP)
      Character idkeyw*72
      Data idkeyw /'@(#)feedi.f        1.2  1/19/93  10:23:00\0'/
      idkeyw = idkeyw
      NRDK = NM + 1
C ***************************************
C *  Calculate Total Integrated crops  *
C ***************************************
      T = 365
      DO 10,I = 1,NCR
         DO 20,J = 1,NM
           Q(J) = CTOTAL(I,J)
 20      CONTINUE
         CALL RDK(T,DX,NRDK,Q,QDX,QIX)
         DO 30,J = 1,NM
           QTIC(I,J) = QIX(J)
           TQC(I,J) = TQC(I,J) + QTIC(I,J)
 30      CONTINUE
 10   CONTINUE

C     prior years crops
C ***************************
C *  Prior Years Crops     *
C ***************************
      IF(T2.NE.0.)THEN
C        load grain and legume into q matrix and integrate over ingestion time
         DO 40,J = 1,NM
          Q(J) = PGRAIN(J)
 40      CONTINUE
         CALL RDK(T2,DX,NRDK,Q,QDX,QIX)
         DO 50,J = 1,NM
           TGRAIN(J) = QIX(J)
           Q(J) = PLEGUME(J)
 50      CONTINUE
         CALL RDK(T2,DX,NRDK,Q,QDX,QIX)
         DO 70,J = 1,NM
           TLEGUME(J) = QIX(J)
 70      CONTINUE
         ELSE
           DO 80,J = 1,NM
             TGRAIN(J) = 0.0
             TLEGUME(J) = 0.0
 80          CONTINUE
      ENDIF
C ***************************
C *  Current Years Crops   *
C ***************************
C     load grain inventories into RDK matrix
      DO 85,J = 1,NM
        Q(J) = CTOTAL(6,J)
 85   CONTINUE
C     decay grain inventory for hold-up time
      T = THGL
      CALL RDK(T,DX,NRDK,Q,QDX,QIX)
      DO 90,J = 1,NM
        Q(J) = QDX(J)
 90   CONTINUE
C     Now integrate grain inventories for time T1
      CALL RDK(T1,DX,NRDK,Q,QDX,QIX)
      DO 100,J = 1,NM
        PGRAIN(J) = QDX(J)
        QTIG(J) = QIX(J)
C        set up matrix for legumes
        Q(J) = CTOTAL(7,J)
 100  CONTINUE
C     decay legume inventory for holdup time
      T = THGL
      CALL RDK(T,DX,NRDK,Q,QDX,QIX)
      DO 120,J = 1,NM
        Q(J) = QDX(J)
 120  CONTINUE
C     Now integrate legume inventory for time T1
      CALL RDK(T1,DX,NRDK,Q,QDX,QIX)
      DO 130,J = 1,NM
         PLEGUME(J) = QDX(J)
```

```
      QTIL(J) = QIX(J)
 130 CONTINUE
     DO 140, J = 1,NM
       QTIG(J) = QTIG(J) + TGRAIN(J)
       QTIL(J) = QTIL(J) + TLEGUME(J)
 140 CONTINUE
     RETURN
     END
C *****************************
C * SUBROUTINE HAY1           *
C *****************************
     SUBROUTINE HAY1(TGROWH,NM,KCUT,QTIH,T1)
C This subroutine calculates the concentration in hay during the year of the
C accident.
C           Variables used in HAY1 Subroutine
C NCUTMAX = MAXIMUM NUMBER OF HAY CUTTINGS (3)
C GTIME = TIME ELASPED FROM START OF GROWING SEASON TO ACCIDENT
C K = NUMBER OF HAY CUTTINGS REAMINING AFTER ACCIDENT
C KCUT = HAY SEASON DURING WHICH ACCIDENT OCCURRED
C KT = CURRENT HAY CUTING SEASON
C KFLAG = FLAG TO INDICAT WHETHER MORE HAY CUTINGS WILL OCCUR AFTER THE ACCIDENT
C QCUT(K,J) = ACTIVITY CONCNETRATION IN HAY CUTTING K (BQ/KG)
C QTH(J) = TOTAL ACTIVITY CONCENTRATION IN HAY (BQ/KG)
C NRDK = NUMBER OF COMPARTMENTS NEEDED TO BE PASSED TO RDK SUBROUTINE
C FVH = FRACTION OF FALLOUT TO HAY SURFACE
C FSH = FRACTION OF FALLOUT TO HAY SOIL SURFACE
     IMPLICIT REAL*8 (A-H,O-Z)
     PARAMETER (MAXP = 4,NMAX = 32,NCUTMAX = 3)
*
*    Identification
*    Program Name: COMIDA
*    Module Name: hay1.f Version 1.2
*    Date: 1/19/93 Time: 10:24:26
*
C HAYPAR.BLK
     COMMON /HAYPAR/ZKGH,BIH,BMAXH,NCUT,TCUT
     DIMENSION TCUT(0:NCUTMAX)
C HAYNUC.BLK
     COMMON /HAYNUC/CRH,ZKABH
     DIMENSION CRH(MAXP),ZKABH(MAXP)
C TIMEPAR.BLK
     COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
    I THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C COMPAR.BLK
     COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
     DIMENSION ALPHA(7)
C HAYSTATE.BLK
     COMMON /HAYSTATE/QVSH,QSSH,QRSH,QVIH,QFSH
     DIMENSION QVSH(MAXP),QSSH(MAXP),QRSH(MAXP),QVIH(MAXP)
    I,QFSH(MAXP)
C PLANT.BLK
     COMMON /PLANT/ ZKG,CR,THICK,RHO,BMAX,BSTART,GTIME
     DIMENSION CR(MAXP)
C ANIMALF.BLK
     COMMON /ANIMALF/ PGRAIN,PLEGUME,PHAY
     DIMENSION PGRAIN(MAXP),PLEGUME(MAXP),PHAY(MAXP)
     COMMON /RCONTANTS/ Z12,Z15,Z21,Z23,Z34,Z3,Z43,D,Z52
     DIMENSION QTH(MAXP),QTIH(MAXP),QCUT(NCUTMAX,MAXP)
     DIMENSION A(NMAX),D(MAXP),Z3(MAXP),Z15(MAXP)
     DIMENSION Q(MAXP + 1),QDX(MAXP + 1),QIX(MAXP + 1),DX(MAXP + 1)
     Character idkeyw*72
     Data idkeyw /'@(#)hay1.f         1.2  1/19/93  10:24:26\0'/
     idkeyw = idkeyw
C    set senescence rate constant to zero and remaining parameters to
C    given values
     Z52 = 0.0
     WRITE(*,*) 'CALCULATING FIRST CALENDER YEAR HAY INVENTORIES '
     NRDK = NM + 1
     BMAX = BMAXH
     BSTART = BIH
     TCUT(0) = TSH
     KFLAG = 0
     Z12 = ZKW
     Z21 = ZKR + ZKRS
     ZKG = ZKGH
     ALPHAX = ALPHA(6)
     DO 10,J = 1,NM
```

```
      CR(J)=CRH(J)
      Z15(J)=ZKABH(J)
      QTH(J)=0.0
      DX(J)=D(J)
      DO 20,I=1,NCUTMAX
        QCUT(I,J)=0.0
20      CONTINUE
10    CONTINUE
    DO 40,J=1,NMAX
      A(J)=0.0
40  CONTINUE
C   ******************************************************************
C   check TGROWH to see if accident occurred during growing season (TGROWH>0)
    IF(TGROWH.GT.0.)THEN
C       accident occurred during growing season, TGROWH=time remaining in
C       current hay crop befor harvest
      X1=0.0
      X2=TGROWH
C       calculate growing time elasped in current hay crop
      GTIME=TI-TCUT(KCUT-1)
C       calculate fallout fractions based on current biomass
C       set initial inventories in compartments; fraction to veg surface (FVH)
C       in A(1) and fraction to soil surface (FSH) to A(2)
      CALL FALLOUT(FVH,FSH,BSTART,BMAX,GTIME,ZKG,ALPHAX)
      A(1)=FVH
      A(2)=FSH
C       Solve those guys !!!!!!!!!!
      CALL RK4SOLVE(A,X1,X2,NM)
C       save results in state variable matrix and RDK decay matrix
C       convert to Bq/kg dry weight
      DO 50,J=1,NM
        QVSH(J)=A(1+(J-1)*8)/BMAXH
C         reset surface activity to zero
        A(1+(J-1)*8)=0.0
        QVIH(J)=A(5+(J-1)*8)/BMAXH
C         reset internal activity to zero
        A(5+(J-1)*8)=0.0
        QCUT(KCUT,J)=QVSH(J)+QVIH(J)
        QSSH(J)=A(2+(J-1)*8)
        QRSH(J)=A(3+(J-1)*8)
        Q(J)=QCUT(KCUT,J)
 50     CONTINUE
C       Assign value to KFLAG.  KFLAG is positive if more hay cuttings
C       are to take place befor the end of the year
      IF(KCUT.LT.NCUT)THEN
        KFLAG=1
C       Decay QCUT end of growing season
      T=TCUT(NCUT)-TCUT(KCUT)
      CALL RDK(T,DX,NRDK,Q,QDX,QIX)
      WRITE(*,*) 'DECAYING FIRST YEAR HAY AFTER ACCIDENT'
      DO 60, J=1,NM
        QCUT(KCUT,J)=QDX(J)
 60     CONTINUE
        ELSE
          KFLAG=-1
        ENDIF
      WRITE(4,1000) KCUT,(QVSH(J),J=1,MAXP),(QSSH(J),J=1,MAXP),
     ! (QRSH(J),J=1,MAXP),(QVIH(J),J=1,MAXP),(QCUT(KCUT,J),J=1,MAXP)

    ENDIF
C   *************************************************************
C   Compare TI and TSH for accident occurance before or after growing season
C   and KFLAG if accident occurred during last hay cutting period of year.

    IF(KFLAG.GT.0.OR.TI.LT.TSH)THEN
C     if TGROWH is less than 0 then run model to start of growing season.
     IF(TGROWH.LT.0.)THEN
C        calculate fallout fractions based on minimum biomass
        TIME=0.0
        CALL FALLOUT(FVH,FSH,BSTART,BMAX,TIME,ZKG,ALPHAX)
        A(1)=FVH
        A(2)=FSH
C         set growth rate constant and foliar absorption rate constants
C         to zero for calculation to start of growing season
        DO 70, J=1,NM
          Z15(J)=0.0
```

```
70      CONTINUE
       ZKG=0.0
       X1=0.0
       X2=TSH-TI
C       Solve those guys !!!!!!!!!!!!!!!
       CALL RK4SOLVE(A,X1,X2,NM)
C       reset growth rate constant and foliar absorption rate constants
       ZKG=ZKGH
       DO 80, J=1,NM
         Z15(J)=ZKABH(J)
80      CONTINUE
      ENDIF
C     now calculate concentrations in hay crop for NCUT-KCUT number of times
C     GTIME is set to zero since no growing time for each hay growing period
C     has elasped.
      K=NCUT-KCUT
      KT=KCUT+1
      GTIME=0.0
      DO 100,I=1,K
       X1=0.0
       X2=TCUT(KT)-TCUT(KT-1)
C       Solve those guys !!!!!!!!!!!!!!!
       CALL RK4SOLVE(A,X1,X2,NM)
       DO 110,J=1,NM
C         Save surficial component of hay inventory in QVSH
         QVSH(J)=A(1+(J-1)*8)/BMAXH
C         Reset surficial inventory on hay to zero; save internal
C         component of hay inventory.
         A(1+(J-1)*8)=0.0
         QVIH(J)=A(5+(J-1)*8)/BMAXH
C         Reset activity inventory IN hay to zero and save surface and labile
C         soil inventory
         A(5+(J-1)*8)=0.0
         QSSH(J)=A(2+(J-1)*8)
         QRSH(J)=A(3+(J-1)*8)
C         sum internal and surficial hay inventory
         QCUT(KT,J)=QVSH(J)+QVIH(J)
C         set RDK decay matrix equal to QCUT
         Q(J)=QCUT(KT,J)
110     CONTINUE
C      Decay current hay cutting to end of hay season
       IF(KT.LT.NCUT)THEN
         T=TCUT(NCUT)-TCUT(KT)
         CALL RDK(T,DX,NRDK,Q,QDX,QIX)
         DO 115, J=1,NM
           QCUT(KT,J)=QDX(J)
115       CONTINUE
       ENDIF
       WRITE(4,1000) KT,(QVSH(J),J=1,MAXP),(QSSH(J),J=1,MAXP),
     !  (QRSH(J),J=1,MAXP),(QVIH(J),J=1,MAXP),(QCUT(KT,J),J=1,MAXP)
       KT=KT+1
100   CONTINUE
      ENDIF

C     ***************************************************************
C     See if accident occurred after growing season
      IF(TI.GE.TCUT(NCUT))THEN
C       put entire inventory in surface soil compartment and calculate TEND
C       which is the time to the end of the year
       A(2)=1.0
       TEND=365-TI
        ELSE
C         calculate concentration in hay from all cuttings
         DO 120, J=1,NM
           DO 130,I=1,NCUT
             QTH(J)=QTH(J)+QCUT(I,J)
130          CONTINUE
C            compute average hay inventory for NCUT cutting. Setup Q matrix
C            for integration using the RDK subroutine
           QTH(J)=QTH(J)/NCUT
           Q(J)=QTH(J)
120        CONTINUE
         WRITE(4,1500) (QTH(J),J=1,NM)
C         decay hay inventory for hold-up time
         T=THHAY
         CALL RDK(T,DX,NRDK,Q,QDX,QIX)
         DO 135,J=1,NM
```

```
         Q(J) = QDX(J)
 135     CONTINUE
C        integrate hay concentration for a time T1 and save inventory
C         in PHAY
         CALL RDK(T1,DX,NRDK,Q,QDX,QIX)
         DO 140,J = 1,NM
          QTIH(J) = QIX(J)
          PHAY(J) = QDX(J)
 140      CONTINUE
         TEND = 365-TCUT(NCUT)
      ENDIF
C     Add to TEND, the time to the start of the next growing season
      TEND = TEND + TSH
C     Calculate concentrations in soil comaprtments to beginning of next growing
C     season for all cases.  Set foliar adsorption and root uptake rate constants to
C     zero for calculation to end of year.
      ZKG = 0.0
      DO 150,J = 1,NM
        Z15(J) = 0.0
 150  CONTINUE
      X1 = 0.0
      X2 = TEND
C     now calculate concentration in soil compartments to begining of next
C     growing season and save in hay state variable matrix.
      CALL RK4SOLVE(A,X1,X2,NM)
C     save results in state variable matrix
      DO 200,J = 1,NM
        QSSH(J) = A(2 + (J-1)*8)
        QRSH(J) = A(3 + (J-1)*8)
        QFSH(J) = A(4 + (J-1)*8)
 200  CONTINUE

      WRITE(4,2000) (QSSH(J),J = 1,MAXP),(QRSH(J),J = 1,MAXP),
     !  (QFSH(J),J = 1,MAXP),(QTIH(J),J = 1,MAXP)


 1000 FORMAT(1X,I1,'th HAY CUTTING FOR nTH YEAR. HAY INVENTORY (QCUT) DE
     !CAYED TO END OF SEASON'
     !/,1X,'QVSH (J) BQ/KG   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'QSSH (J) BQ/M2   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'QRSH (J) BQ/M2   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'QVIH (J) BQ/KG   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'QCUT (J) BQ/KG   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2)
 1500 FORMAT(1X,'QTH (J)',1X,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1X,'(Total hay conc a
     !conc at end of growing season Bq/kg)')
 2000 FORMAT(1X,'SOIL INVENTORIES AND ONE YEAR INTEGRATED HAY '
     !/,1X,'QSSH (J) BQ/M2   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'QRSH (J) BQ/M2   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'QFIH (J) BQ/M2   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'QTIH (J) BQ-D/KG ',1PE9.2,1PE9.2,1PE9.2,1PE9.2)

      RETURN
      END
C ******************************
C *  SUBROUTINE HAYN          *
C ******************************
      SUBROUTINE HAYN(NM,QTIH,T1,T2)
C This subroutine calculates the activity inventory in hay for n years
C after the accident
C KT = CURRENT HAY CUTING SEASON
C QCUT(K,J) = ACTIVITY CONCNETRATION IN HAY CUTTING K (BQ/KG)
C QTH(J) = TOTAL ACTIVITY CONCENTRATION IN HAY (BQ/KG)
C NRDK = NUMBER OF COMPARTMENTS TO BE PASSED TO THE RDK SUBROUTINE
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (MAXP = 4,NMAX = 32,NCUTMAX = 3)
*
*     Identification
*     Program Name: COMIDA
*     Module Name: hayn.f Version 1.2
*     Date: 1/19/93  Time: 10:25:30
*
C HAYPAR.BLK
      COMMON /HAYPAR/ZKGH,BIH,BMAXH,NCUT,TCUT
      DIMENSION TCUT(0:NCUTMAX)
C HAYNUC.BLK
      COMMON /HAYNUC/CRH,ZKABH
      DIMENSION CRH(MAXP),ZKABH(MAXP)
```

```
C TIMEPAR.BLK
     COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
    I THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C COMPAR.BLK
     COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
     DIMENSION ALPHA(7)
C HAYSTATE.BLK
     COMMON /HAYSTATE/QVSH,QSSH,QRSH,QVIH,QFSH
     DIMENSION QVSH(MAXP),QSSH(MAXP),QRSH(MAXP),QVIH(MAXP)
    I,QFSH(MAXP)
C PLANT.BLK
     COMMON /PLANT/ ZKG,CR,THICK,RHO,BMAX,BSTART,GTIME
     DIMENSION CR(MAXP)
C ANIMALF.BLK
     COMMON /ANIMALF/ PGRAIN,PLEGUME,PHAY
     DIMENSION PGRAIN(MAXP),PLEGUME(MAXP),PHAY(MAXP)
     COMMON /RCONTANTS/ Z12,Z15,Z21,Z23,Z34,Z3,Z43,D,Z52
     DIMENSION A(NMAX),D(MAXP),Z3(MAXP),Z15(MAXP)
     DIMENSION QTIH(MAXP),QTH(MAXP),QCUT(NCUTMAX,MAXP),THAY(MAXP)
     DIMENSION Q(MAXP+1),QDX(MAXP+1),QIX(MAXP+1),DX(MAXP+1)
     Character idkeyw*72
     Data idkeyw /'@(#)hayn.f          1.2  1/19/93  10:25:30\0'/
     idkeyw = idkeyw
     WRITE(*,*) 'CALCULATING nTH CALENDER YEAR HAY INVENTORIES '
C initialize activity matrix and set senescence rate constant to zero
     Z52=0.0
     NRDK=NM+1
     DO 10,J=1,NMAX
       A(J)=0.0
 10  CONTINUE
C set initial and maximum biomass and growth rate constant
C set TCUT(0) equal to the start of the hay growing season
     BMAX=BMAXH
     BSTART=BIH
     TCUT(0)=TSH
     Z12=ZKW
     Z21=ZKR+ZKRS
     ZKG=ZKGH
C    set initial inventories, concentration factors, and foliar absorption
C    rate constants
     DO 20,J=1,NM
       A(2+(J-1)*8)=QSSH(J)
       A(3+(J-1)*8)=QRSH(J)
       A(4+(J-1)*8)=QFSH(J)
       CR(J)=CRH(J)
       Z15(J)=ZKABH(J)
       QTH(J)=0.0
       DX(J)=D(J)
       DO 30,I=1,NCUTMAX
        QCUT(I,J)=0.0
 30     CONTINUE
 20  CONTINUE

C      now calculate concentrations in hay crop for NCUT number of times
C      GTIME is set to zero since none of each hay growing season time has elasped
      GTIME=0.0
      KT=1
      DO 100,I=1,NCUT
       X1=0.0
       X2=TCUT(KT)-TCUT(KT-1)
C       Solve those guys !!!!!!!!!!!!!!!
       CALL RK4SOLVE(A,X1,X2,NM)
       DO 110,J=1,NM
        QVSH(J)=A(1+(J-1)*8)/BMAXH
C        reset activity inventory ON hay to zero
        A(1+(J-1)*8)=0.0
        QVIH(J)=A(5+(J-1)*8)/BMAXH
C        reset activity inventory IN hay to zero
        A(5+(J-1)*8)=0.0
        QSSH(J)=A(2)
        QRSH(J)=A(3)
C        sum total inventory  and set equal to RDK decay matrix
        QCUT(KT,J)=QVSH(J)+QVIH(J)
        Q(J)=QCUT(KT,J)
 110    CONTINUE
C       decay QCUT to end of hay growing season
       IF(KT.LT.NCUT)THEN
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```
        T = TCUT(NCUT)-TCUT(KT)
        CALL RDK(T,DX,NRDK,Q,QDX,QIX)
        DO 115, J = 1,NM
          QCUT(KT,J) = QDX(J)
 115      CONTINUE
       ENDIF
       WRITE(4,1000) KT,(QVSH(J),J = 1,MAXP),(QSSH(J),J = 1,MAXP),
     ! (QRSH(J),J = 1,MAXP),(QVIH(J),J = 1,MAXP),(QCUT(KT,J),J = 1,MAXP)
       KT = KT + 1
 100  CONTINUE
C ------- end of hay concentration calculations
C    Now sum each hay crop in the variable QTH
     DO 120, J = 1,NM
       DO 130,I = 1,NCUT
        QTH(J) = QTH(J) + QCUT(I,J)
 130    CONTINUE
C       average hay inventory with number of cutting and set Q matrix for decay calculation
       QTH(J) = QTH(J)/NCUT
 120 CONTINUE
     WRITE(4,1500) (QTH(J),J = 1,NM)
C + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
C    Integrate prior years hay inventory
     IF(T2.GT.0.)THEN
       DO 140,J = 1,NM
        Q(J) = PHAY(J)
 140    CONTINUE
       CALL RDK(T2,DX,NRDK,Q,QDX,QIX)
       DO 150,J = 1,NM
         THAY(J) = QIX(J)
 150    CONTINUE
     ENDIF
C    Decay current year hay concentration for hold-up time
     DO 160, J = 1,NM
       Q(J) = QTH(J)
 160 CONTINUE
     T = THHAY
     CALL RDK(T,DX,NRDK,Q,QDX,QIX)
     DO 170,J = 1,NM
       Q(J) = QDX(J)
 170 CONTINUE
C    integrate hay concentration for a time T1 and save inventory
C    in PHAY
     CALL RDK(T1,DX,NRDK,Q,QDX,QIX)
     DO 175,J = 1,NM
        QTIH(J) = QIX(J)
        PHAY(J) = QDX(J)
 175 CONTINUE
C    calculate total integrated inventory
     DO 180,J = 1,NM
        QTIH(J) = QTIH(J) + THAY(J)
 180 CONTINUE
C + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
C    Calculate concentrations in soil compartments to beginning of next
C    hay growing season.  Set root uptake and foliar absorption rate constants
C    to zero.
     TEND = 365-TCUT(NCUT) + TSH
     ZKG = 0.0
     DO 185, J = 1,NM
       Z15(J) = 0.0
 185 CONTINUE
     X1 = 0.0
     X2 = TEND
C now calculate concentration in soil compartments to beginning of next growing
C season and save values in hay state variable matrix.
       CALL RK4SOLVE(A,X1,X2,NM)
C save results in state variable matrix
       DO 200,J = 1,NM
          QSSH(J) = A(2 + (J-1)*8)
          QRSH(J) = A(3 + (J-1)*8)
          QFSH(J) = A(4 + (J-1)*8)
 200      CONTINUE

       WRITE(4,2000) (QSSH(J),J = 1,MAXP),(QRSH(J),J = 1,MAXP),
     ! (QFSH(J),J = 1,MAXP),(QTIH(J),J = 1,MAXP)

 1000 FORMAT(1X,I1,'th HAY CUTTING FOR nTH YEAR. HAY INVETORY (QCUT) DEC
     !AYED TO END SEASON'
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```
     1/,1X,'QVSH (J)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QSSH (J)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QRSH (J)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QVIH (J)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QCUT (J)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1X,'(decayed to en
     1d of season)')

 1500 FORMAT(1X,'QTH (J)',1X,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1X,'(hay conc a
     1t end of growing season with no decay for hold-up time)')
 2000 FORMAT(1X,'SOIL INVENTORIES AND ONE YEAR INTEGRATED HAY '
     1/,1X,'QSSH (J)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QRSH (J)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QFIH (J)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QTIH (J)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2)

      RETURN
      END
C ******************************
C *  SUBROUTINE PASTURE1       *
C ******************************
      SUBROUTINE PASTURE1(TGROWP,NM,QTIP,QIPS,QSTIP,QSTIS)
C     This subroutine calculates the concentration in pasture for the first
C     365 days following the accident.
      IMPLICIT REAL*8 (A-H,O-Z)
C     GTIME=TIME ELASPED FROM START OF GROWING SEASON
C     QSTIP(J)=SHORT TERM INTEGRATED PASTURE ACTIVITY (including soil) (BQ-D/KG)
      PARAMETER (MAXP=4,NMAX=32)
*
*     Identification
*     Program Name: COMIDA
*     Module Name: pasture1.f Version 1.2
*     Date: 1/19/93 Time: 10:27:26
*
C PASTPAR.BLK
      COMMON /PASTPAR/ZKGP,BIP,BMAXP,ZSEN
C PASTNUC.BLK
      COMMON /PASTNUC/CRP,ZKABP
      DIMENSION CRP(MAXP),ZKABP(MAXP)
C PASTSTAT.BLK
      COMMON /PASTSTATE/QVSP,QSSP,QRSP,QVIP,QFSP
      DIMENSION QVSP(MAXP),QSSP(MAXP),QRSP(MAXP),QVIP(MAXP)
     1,QFSP(MAXP)
C COMPAR.BLK
      COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
      DIMENSION ALPHA(7)
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     1 THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C PLANT.BLK
      COMMON /PLANT/ ZKG,CR,THICK,RHO,BMAX,BSTART,GTIME
      DIMENSION CR(MAXP)
      COMMON /RCONTANTS/ Z12,Z15,Z21,Z23,Z34,Z3,Z43,D,Z52
      DIMENSION A(NMAX),D(MAXP),Z3(MAXP),Z15(MAXP)
     1,QTIP(MAXP),QIPS(MAXP),QSTIP(MAXP),QSTIS(MAXP)
      Character idkeyw*72
      Data idkeyw /'@(#)pasture1.f      1.2  1/19/93  10:27:26\0'/
      idkeyw=idkeyw
      WRITE(*,*) 'CALCULATING FIRST YEAR PASTURE AND SOIL INVENTORIES '
C     initialize state variables
      DO 10,J=1,NMAX
         A(J)=0.0
   10 CONTINUE
C     Set initial values for weathering and resuspention rate constants and
C     concentration ratio values and alpha value to ALPHA(7).
      Z52=ZSEN
      DO 20,J=1,NM
        CR(J)=CRP(J)
   20 CONTINUE
      X1=0.0
      Z12=ZKW
      Z21=ZKR+ZKRS
      BMAX=BMAXP
      BSTART=BIP
      ALPHAX=ALPHA(7)

C          *************************************************
C          * CASE 1: Accident Occurred During Growing Season *
```

```
C        *     and Before Grazing Season          *
C        ************************************************

   IF(TGROWP.GT.0.AND.TI.LT.TSL)THEN
     ZKG=ZKGP
     Z52=0.0
C     calculate time elasped in growing season
     GTIME=TI-TSP
C     calculate fallout fractions
     CALL FALLOUT(FVP,FSP,BSTART,BMAX,GTIME,ZKG,ALPHAX)
     A(1)=FVP
     A(2)=FSP
C     set foliar absorption rate constants
     DO 30,J=1,NM
       Z15(J)=ZKABP(J)
 30    CONTINUE
C     calculate concentration on pasture to the start of the grazing season.
     X2a=TSL-TI
     CALL RK4SOLVE(A,X1,X2a,NM)
C     set X2b to the duration of the livestock grazing season
C     and clear integrated vegetation compartments.
     X2b=TEL-TSL
     GTIME=X2a
     DO 50,J=1,NM
       A(6+(J-1)*8)=0.0
       A(8+(J-1)*8)=0.0
 50    CONTINUE
C     calculate short term integrated pasture concentration and livestock
C     season pasture concentration
     CALL SHORT(NM,A,QSTIP,QSTIS)
     CALL RK4SOLVE(A,X1,X2b,NM)
C     Save pasture results in integrated state variable compartments
     DO 80,J=1,NM
       QTIP(J)=(A(6+(J-1)*8)+A(8+(J-1)*8))
 80    CONTINUE
C     Run model for the non-growing season. Only root uptake and foliar
C     absorption rate constants are set to zero since weathering and
C     resuspention can occur year round.
     ZKG=0.0
     Z52=ZSEN
     DO 90,J=1,NM
       Z15(J)=0.0
 90    CONTINUE
     X2c=365-TEL+TSP
     CALL RK4SOLVE(A,X1,X2c,NM)
C     Run model from the start of the growing season to the end of the
C     accident year. Save soil inventories in state variable matrix. Set
C     ZSEN to zero and run model only if X2 is greater than zero
     Z52=0.0
     DO 100,J=1,NM
       Z15(J)=ZKABP(J)
 100   CONTINUE
     ZKG=ZKGP
     GTIME=0.0
     X2=TI-TSP
     IF(X2.GT.0.)THEN
       CALL RK4SOLVE(A,X1,X2,NM)
     ENDIF
C     save integrated soil results
     DO 110,J=1,NM
       QIPS(J)=A(7+(J-1)*8)/(PSS*XS)
 110   CONTINUE
   ENDIF

C        ************************************************
C        * CASE 2: Accident Occurred During Grazing Season *
C        ************************************************

   IF(TGROWP.GT.0.AND.TI.GE.TSL)THEN
     ZKG=ZKGP
     Z52=0.0
C     calculate time elasped in growing season
     GTIME=TI-TSP
C     calculate fallout fractions
     CALL FALLOUT(FVP,FSP,BSTART,BMAX,GTIME,ZKG,ALPHAX)
     A(1)=FVP
     A(2)=FSP
```

```
C       set foliar absorption rate constants
        DO 120,J=1,NM
           Z15(J)=ZKABP(J)
 120     CONTINUE
C       Set X2a to the remainder of the livestock grazing season
        X2a=TEL-TI
C       calculate short term integrated pasture concentration and livestock
C       season pasture concentration
        CALL SHORT(NM,A,QSTIP,QSTIS)
        CALL RK4SOLVE(A,X1,X2a,NM)
C       save pasture results in the integrated state variable matrix
C       Pasture veg values are returned in units of Bq-D/kg
        DO 140,J=1,NM
           QTIP(J)=(A(6+(J-1)*8)+A(8+(J-1)*8))
 140    CONTINUE
C       Run model for the non-growing season.
        ZKG=0.0
        Z52=ZSEN
        DO 150,J=1,NM
          Z15(J)=0.0
 150    CONTINUE
        X2b=365-TEL+TSP
        CALL RK4SOLVE(A,X1,X2b,NM)
C       Run model from the start of the growing season to the start of the
C       next livestock season
        Z52=0.0
        GTIME=0.0
        DO 160,J=1,NM
         Z15(J)=ZKABP(J)
 160    CONTINUE
        ZKG=ZKGP
        X2c=TSL-TSP
        CALL RK4SOLVE(A,X1,X2c,NM)
C       reset integrated pasture compartments
        DO 170, J=1,NM
          A(6+(J-1)*8)=0.0
          A(8+(J-1)*8)=0.0
 170    CONTINUE
C       Run model from the start of the livestock season to the end
C       of the accident year and save results.  Perform integration
C       only if X2 is greater than zero.
        X2=TI-TSL
        GTIME=X2c
        IF(X2.GT.0.)THEN
          CALL RK4SOLVE(A,X1,X2,NM)
        ENDIF
C       Save integrated soil and pasture results
        DO 180,J=1,NM
          QIPS(J)=A(7+(J-1)*8)/(PSS*XS)
          QTIP(J)=QTIP(J)+(A(6+(J-1)*8)+A(8+(J-1)*8))
 180    CONTINUE
      ENDIF

C          ******************************************************
C          * CASE 3: Accident Occurs Before or After Growing Season *
C          ******************************************************

      IF(TGROWP.LE.0.0)THEN
C      calculate fallout fraction based on minimum biomass and no growth
       GTIME=0.0
       CALL FALLOUT(FVP,FSP,BSTART,BMAX,GTIME,ZKG,ALPHAX)
       A(1)=FVP
       A(2)=FSP
C      Compute time to run model during non-growing season
       IF(TI.GE.TEL)THEN
        X2a=365-TI+TSP
         ELSE
          X2a=TSP-TI
       ENDIF
C      run model to start of growing season setting root uptake and
C      foliar adsorption rate constant to zero.
       DO 200,J=1,NM
        Z15(J)=0.0
 200   CONTINUE
       ZKG=0.0
C      Solve those guys !!!!!!!!!!!!!!!
       CALL RK4SOLVE(A,X1,X2a,NM)
```

```
C      now calculate concentrations in pasture to the start of livestock
C      grazing season given the initial soil inventories in compartments
C      A(2), A(3) AND A(4). GTIME is kept at zero since none of the growing
C      season has elapsed
       ZKG=ZKGP
       Z52=0.0
       DO 210,J=1,NM
         Z15(J)=ZKABP(J)
 210   CONTINUE
       X2b=TSL-TSP
       CALL RK4SOLVE(A,X1,X2b,NM)
C      now calculate for inventories and integrated amounts for the livestock
C      grazing season. Reset the integrated vegetation compartments to zero
C      since the no ingestion has taken place and GTIME to growth for pasture

       GTIME=X2b
       X2c=TEL-TSL
       DO 220,J=1,NM
            A(6+(J-1)*8)=0.0
            A(8+(J-1)*8)=0.0
 220   CONTINUE
       CALL SHORT(NM,A,QSTIP,QSTIS)
       CALL RK4SOLVE(A,X1,X2c,NM)
C      save integrated pasture results in state variable matrix
       DO 250,J=1,NM
         QTIP(J)=(A(6+(J-1)*8)+A(8+(J-1)*8))
 250   CONTINUE
C      Run model for the remaining time in the accident year setting growth
C      rate constant and foliar absorption rate constants to zero and sen rate
C      constant to given value
       X2=365-(X2a+X2b+X2c)
       ZKG=0.0
       Z52=ZSEN
       DO 260,J=1,NM
         Z15(J)=0.0
 260   CONTINUE
C      Perform integration only if X2 is greater than zero
       IF(X2.GT.0.)THEN
         CALL RK4SOLVE(A,X1,X2,NM)
       ENDIF
C      save the integrated soil results
       DO 270, J=1,NM
         QIPS(J)=A(7+(J-1)*8)/(PSS*XS)
 270   CONTINUE

      ENDIF
C     save invetories in pasture state variables
      DO 280, J=1, NM
         QVSP(J)=A(1+(J-1)*8)
         QSSP(J)=A(2+(J-1)*8)
         QRSP(J)=A(3+(J-1)*8)
         QFSP(J)=A(4+(J-1)*8)
         QVIP(J)=A(5+(J-1)*8)
 280  CONTINUE

      WRITE(4,1000) (QVSP(J),J=1,MAXP),(QVIP(J),J=1,MAXP),
     1(QSSP(J),J=1,MAXP),(QRSP(J),J=1,MAXP),(QFSP(J),J=1,MAXP)

 1000 FORMAT(1X,'PASTURE INVENTORIES AT THE END OF ONE ACCIDENT YEAR'
     1/,1X,'QVSP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QVIP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QSSP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QRSP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QFSP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2)
      Z52=0.0
      RETURN
      END
C ******************************
C *  SUBROUTINE PASTUREN       *
C ******************************
      SUBROUTINE PASTUREN(TGROWP,NM,QTIP,QIPS)
C     This subroutine calculates the concentration in pasture for the any
C     365 day period following the accident.
      IMPLICIT REAL*8 (A-H,O-Z)
C     GTIME=TIME ELASPED FROM START OF GROWING SEASON
      PARAMETER (MAXP=4,NMAX=32)
*
```

```
*   Identification
*   Program Name: COMIDA
*   Module Name: pasturen.f Version 1.3
*   Date: 1/19/93 Time: 10:29:17
*
C PASTPAR.BLK
    COMMON /PASTPAR/ZKGP,BIP,BMAXP,ZSEN
C PASTNUC.BLK
    COMMON /PASTNUC/CRP,ZKABP
    DIMENSION CRP(MAXP),ZKABP(MAXP)
C PASTSTAT.BLK
    COMMON /PASTSTATE/QVSP,QSSP,QRSP,QVIP,QFSP
    DIMENSION QVSP(MAXP),QSSP(MAXP),QRSP(MAXP),QVIP(MAXP)
   !,QFSP(MAXP)
C COMPAR.BLK
    COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
    DIMENSION ALPHA(7)
C TIMEPAR.BLK
    COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
   ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C PLANT.BLK
    COMMON /PLANT/ ZKG,CR,THICK,RHO,BMAX,BSTART,GTIME
    DIMENSION CR(MAXP)
    COMMON /RCONTANTS/ Z12,Z15,Z21,Z23,Z34,Z3,Z43,D,Z52
    DIMENSION A(NMAX),D(MAXP),Z3(MAXP),Z15(MAXP)
   !,QTIP(MAXP),QIPS(MAXP)
    Character idkeyw*72
    Data idkeyw /'@(#)pasturen.f      1.3  1/19/93  10:29:17\0'/
    idkeyw = idkeyw
    WRITE(*,*) 'CALCULATING nth YEAR PASTURE AND SOIL INVENTORIES '

C   Initialize state variables
    DO 10,J=1,NMAX
       A(J)=0.0
 10 CONTINUE

C   Set initial values for weathering and resuspention rate constants and
C   concentration ratio values. Set senescence rate constant to zero and
C   alpha value to ALPHA(7) and initial inventories in compartments .

    DO 20,J=1,NM
      CR(J)=CRP(J)
      A(1+(J-1)*8)=QVSP(J)
      A(2+(J-1)*8)=QSSP(J)
      A(3+(J-1)*8)=QRSP(J)
      A(4+(J-1)*8)=QFSP(J)
      A(5+(J-1)*8)=QVIP(J)
 20 CONTINUE
    X1=0.0
    Z12=ZKW
    Z21=ZKR+ZKRS
    BMAX=BMAXP
    BSTART=BIP

C        ***********************************************
C        * CASE 1: Accident Occurred During Growing Season *
C        *       and Before Grazing Season          *
C        ***********************************************

    IF(TGROWP.GT.0.AND.TI.LT.TSL)THEN
      ZKG=ZKGP
C     calculate time elasped in growing season
      GTIME=TI-TSP
C     set foliar absorption rate constants
      DO 30,J=1,NM
         Z15(J)=ZKABP(J)
 30   CONTINUE
C     calculate concentration on pasture to the start of the grazing season.
      X2a=TSL-TI
      CALL RK4SOLVE(A,X1,X2a,NM)
C     set X2b to the duration of the livestock grazing season and GTIME to X2a
C     and clear integrated vegetation compartments.
      GTIME=X2a
      X2b=TEL-TSL
      DO 50,J=1,NM
        A(6+(J-1)*8)=0.0
        A(8+(J-1)*8)=0.0
```

```
 50    CONTINUE
C      calculate livestock season pasture concentration
       CALL RK4SOLVE(A,X1,X2b,NM)
C      Save pasture results in integrated state variable compartments
       DO 80,J=1,NM
         QTIP(J)=(A(6+(J-1)*8)+A(8+(J-1)*8))
 80    CONTINUE
C      Run model for the non-growing season. The senescence rate constant is
C      assigned the value of ZSEN.
       ZKG=0.0
       Z52=ZSEN
       DO 90,J=1,NM
        Z15(J)=0.0
 90    CONTINUE
       X2c=365-TEL+TSP
       CALL RK4SOLVE(A,X1,X2c,NM)
C      Run model from the start of the growing season to the end of the
C      accident year. Save soil inventories in state variable matrix. Set
C      the GTIME variable to zero since no part of the growing season as elasped
       GTIME=0.0
       Z52=0.0
       DO 100,J=1,NM
        Z15(J)=ZKABP(J)
 100   CONTINUE
       ZKG=ZKGP
       X2=TI-TSP
       IF(X2.GT.0.)THEN
         CALL RK4SOLVE(A,X1,X2,NM)
       ENDIF
C      save integrated soil results
       DO 110,J=1,NM
         QIPS(J)=A(7+(J-1)*8)/(PSS*XS)
 110   CONTINUE
     ENDIF

C        ***********************************************
C        * CASE 2: Accident Occurred During Grazing Season *
C        ***********************************************

     IF(TGROWP.GT.0.AND.TI.GE.TSL)THEN
       ZKG=ZKGP
C      calculate time elasped in growing season
       GTIME=TI-TSP
C      set foliar absorption rate constants
       DO 120,J=1,NM
          Z15(J)=ZKABP(J)
 120   CONTINUE
C      Set X2a to the remainder of the livestock grazing season
       X2a=TEL-TI
C      calculate livestock season pasture concentration
       CALL RK4SOLVE(A,X1,X2a,NM)
C      save pasture results in the integrated state variable matrix
       DO 140,J=1,NM
          QTIP(J)=(A(6+(J-1)*8)+A(8+(J-1)*8))
 140   CONTINUE
C      Run model for the non-growing season.
       ZKG=0.0
       Z52=ZSEN
       DO 150,J=1,NM
         Z15(J)=0.0
 150   CONTINUE
       X2b=365-TEL+TSP
       CALL RK4SOLVE(A,X1,X2b,NM)
C      Run model from the start of the growing season to the start of the
C      next livestock season. Set GTIME to zero for begining of growing season
       Z52=0.0
       GTIME=0.0
       DO 160,J=1,NM
        Z15(J)=ZKABP(J)
 160   CONTINUE
       ZKG=ZKGP
       X2c=TSL-TSP
       CALL RK4SOLVE(A,X1,X2c,NM)
C      reset integrated pasture compartments
       DO 170, J=1,NM
         A(6+(J-1)*8)=0.0
         A(8+(J-1)*8)=0.0
```

```
170   CONTINUE
C      Run model from the start of the livestock season to the end
C      of the accident year and save results
      X2=TI-TSL
      GTIME=X2c
      IF(X2.GT.0.)THEN
        CALL RK4SOLVE(A,X1,X2,NM)
      ENDIF
      DO 180,J=1,NM
        QIPS(J)=A(7+(J-1)*8)/(PSS*XS)
        QTIP(J)=QTIP(J)+(A(6+(J-1)*8)+A(8+(J-1)*8))
180   CONTINUE
    ENDIF

C         ****************************************************
C         * CASE 3: Accident Occurs Before or After Growing Season *
C         ****************************************************
    IF(TGROWP.LE.0.0)THEN
      GTIME=0.0
      Z52=ZSEN
C      Compute time to run model during non-growing season
      IF(TI.GE.TEL)THEN
       X2a=365-TI+TSP
        ELSE
         X2a=TSP-TI
      ENDIF
C      run model to start of growing season setting root uptake and
C      foliar adsorption rate constant to zero.
      DO 200,J=1,NM
        Z15(J)=0.0
200   CONTINUE
      ZKG=0.0
      CALL RK4SOLVE(A,X1,X2a,NM)
C      now calculate concentrations in pasture to the start of livestock
C      grazing season given the initial soil inventories in compartments
C      A(2), A(3) AND A(4). GTIME is kept at zero since none of the growing
C      season has elasped and senecence rate constant (Z52) is set to zero
      ZKG=ZKGP
      Z52=0.0
      DO 210,J=1,NM
        Z15(J)=ZKABP(J)
210   CONTINUE
      X2b=TSL-TSP
      CALL RK4SOLVE(A,X1,X2b,NM)
C      now calculate for inventories and integrated amounts for the livestock
C      grazing season. Reset the integrated vegetation compartments to zero
C      since the no ingestion has taken place and GTIME to growth time for pasture
      GTIME=X2b
      X2c=TEL-TSL
      DO 220,J=1,NM
          A(6+(J-1)*8)=0.0
          A(8+(J-1)*8)=0.0
220   CONTINUE
      CALL RK4SOLVE(A,X1,X2c,NM)
C      save integrated pasture results in state variable matrix
      DO 250,J=1,NM
        QTIP(J)=(A(6+(J-1)*8)+A(8+(J-1)*8))
250   CONTINUE
C      Run model for the remaining time in the accident year setting growth
C      rate constant and foliar absorption rate constants to zero
      X2=365-(X2a+X2b+X2c)
      ZKG=0.0
      Z52=ZSEN
      DO 260,J=1,NM
        Z15(J)=0.0
260   CONTINUE
      IF(X2.GT.0.)THEN
        CALL RK4SOLVE(A,X1,X2,NM)
      ENDIF
C      save the integrated soil results
      DO 270, J=1,NM
        QIPS(J)=A(7+(J-1)*8)/(PSS*XS)
270   CONTINUE
    ENDIF
C   Save compartmental results
    DO 280, J=1,NM
        QVSP(J)=A(1+(J-1)*8)
```

```
      QSSP(J) = A(2 + (J-1)*8)
      QRSP(J) = A(3 + (J-1)*8)
      QFSP(J) = A(4 + (J-1)*8)
      QVIP(J) = A(5 + (J-1)*8)
 280  CONTINUE
      WRITE(4,1000) (QVSP(J),J = 1,MAXP),(QVIP(J),J = 1,MAXP),
     1(QSSP(J),J = 1,MAXP),(QRSP(J),J = 1,MAXP),(QFSP(J),J = 1,MAXP)

 1000 FORMAT(1X,'PASTURE INVENTORIES AT THE END OF THE nth YEAR FOLLOWIN
     1G ACCIDENT'
     1/,1X,'QVSP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QVIP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QSSP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QRSP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2
     1/,1X,'QFSP(J) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2)
      Z52 = 0.0
      RETURN
      END
C *****************************
C *  SUBROUTINE BEEF          *
C *****************************
      SUBROUTINE BEEF(NM,QTIG,QTIL,QTIH,QTIP,QIPS)
C This subroutine calculates the integrated activity in beef for any year
C intake of contaminanted hay pasture or grain
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (MAXP = 4)
*
*     Identification
*     Program Name: COMIDA
*     Module Name: beef.f Version 1.2
*     Date: 1/19/93 Time: 10:30:07
*
C BEEFPAR.BLK
      COMMON /BEEFPAR/RPB,RHB,RGB,RSB,RLB
C BEEFNUC.BLK
      COMMON /BEEFNUC/TCB,TCM
      DIMENSION TCB(MAXP),TCM(MAXP)
C BEEFSTAT.BLK
      COMMON /BEEFSTATE/QIBP,QIBH,QIBG,QIBS,QIBT,QIBL,TQB
      DIMENSION QIBP(MAXP),QIBH(MAXP),QIBG(MAXP),QIBS(MAXP),QIBT(MAXP)
     1,QIBL(MAXP),TQB(MAXP)
C NUCPAR1.BLK
      COMMON /NUCPAR1/NMEMBER,NPROG,THALF,ZKL
      DIMENSION THALF(MAXP),ZKL(MAXP)
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     1 THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C     state variables
      DIMENSION QTIG(MAXP),QTIH(MAXP),QTIP(MAXP),QIPS(MAXP),QTIL(MAXP),
     1D(MAXP)
      Character idkeyw*72
      Data idkeyw /'@(#)beef.f        1.2  1/19/93  10:30:07\0'/
      idkeyw = idkeyw
C     Set decay rate constant array such that decay is only accounted
C     for with parent nuclides.
      DO 5,J = 1,NM
       D(J) = 0.0
 5    CONTINUE
      D(1) = LOG(2.)/THALF(1)
C     Calculate contribution from pasture, hay, grain, soil, legumes and total
C     Store accumulated yearly total in TQB
      DO 10,J = 1,NM
        QIBP(J) = QTIP(J)*RPB*TCB(J)*EXPF(-D(J)*THBEEF)
        QIBH(J) = QTIH(J)*RHB*TCB(J)*EXPF(-D(J)*THBEEF)
        QIBG(J) = QTIG(J)*RGB*TCB(J)*EXPF(-D(J)*THBEEF)
        QIBS(J) = QIPS(J)*RSB*TCB(J)*EXPF(-D(J)*THBEEF)
        QIBL(J) = QTIL(J)*RLB*TCB(J)*EXPF(-D(J)*THBEEF)
        QIBT(J) = (QIBP(J) + QIBH(J) + QIBG(J) + QIBL(J) + QIBS(J))
        TQB(J) = TQB(J) + QIBT(J)
C       WRITE(*,*) TQB(J)
 10   CONTINUE
      RETURN
      END
C *****************************
C *  SUBROUTINE MILK          *
C *****************************
      SUBROUTINE MILK(NM,QTIG,QTIH,QTIP,QIPS,QTIL,QSTIP,QSTIS,NY)
```

```
C This subroutine calculates the integrated activity in milk for any year
C intake of contaminanted hay pasture or grain
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (MAXP=4)
*
*     Identification
*     Program Name: COMIDA
*     Module Name: milk.f Version 1.2
*     Date: 1/19/93 Time: 10:31:32
*
C MILKPAR.BLK
      COMMON /MILKPAR/RPM,RHM,RGM,RSM,RLM
C BEEFNUC.BLK
      COMMON /BEEFNUC/TCB,TCM
      DIMENSION TCB(MAXP),TCM(MAXP)
C MILKSTAT.BLK
      COMMON /MILKSTATE/QIMP,QIMH,QIMG,QIMS,QIMT,QIML,QISM,TQM
      DIMENSION QIMP(MAXP),QIMH(MAXP),QIMG(MAXP),QIMS(MAXP),QIMT(MAXP)
     !,QIML(MAXP),QISM(MAXP),TQM(MAXP)
C NUCPAR1.BLK
      COMMON /NUCPAR1/NMEMBER,NPROG,THALF,ZKL
      DIMENSION THALF(MAXP),ZKL(MAXP)
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
      DIMENSION QTIG(MAXP),QTIH(MAXP),QTIP(MAXP),QIPS(MAXP),QTIL(MAXP),
     ! QSTIP(MAXP),QSTIS(MAXP),D(MAXP)
      Character idkeyw*72
      Data idkeyw /'@(#)milk.f         1.2 1/19/93 10:31:32\0'/
      idkeyw=idkeyw

C     Calculate contribution from pasture, hay, grain legumes, soil and total
C     Store total accumulated yearly total in TQM
C     Set decay rate constant array such that decay is only accounted
C     for with parent nuclides.
      DO 5,J=1,NM
       D(J)=0.0
 5    CONTINUE
      D(1)=LOG(2.)/THALF(1)
      DO 10,J=1,NM
        QIMP(J)=QTIP(J)*RPM*TCM(J)*EXPF(-D(J)*THMILK)
        QIMH(J)=QTIH(J)*RHM*TCM(J)*EXPF(-D(J)*THMILK)
        QIMG(J)=QTIG(J)*RGM*TCM(J)*EXPF(-D(J)*THMILK)
        QIMS(J)=QIPS(J)*RSM*TCM(J)*EXPF(-D(J)*THMILK)
        QIML(J)=QTIL(J)*RLM*TCM(J)*EXPF(-D(J)*THMILK)
        QIMT(J)=(QIMP(J)+QIMH(J)+QIMG(J)+QIMS(J)+QIML(J))
        IF(NY.EQ.1)THEN
          QISM(J)=(QSTIP(J)*RPM*TCM(J)+QSTIS(J)*RSM*TCM(J))*EXPF(-D(J)*
     ! THMILK)
        ENDIF
        TQM(J)=TQM(J)+QIMT(J)
 10   CONTINUE
      RETURN
      END
C ******************************
C * SUBROUTINE SHORT          *
C ******************************
      SUBROUTINE SHORT(NM,A,QSTIP,QSTIS)
C This subroutine calculates the short term integrated activity in pasture
      IMPLICIT REAL*8 (A-H,O-Z)
C     T=ACTUAL INTEGRATION TIME
C     B=DUMMY MATRIX TO HOLD STATE VARIABLE VALUES
C     X1=BEGINNING TIME (SET EQUAL TO ZERO)
C     QSTIP(J)=SHORT TERM INTEGRATED PASTURE ACTIVITY (BQ-D/KG)
C     QSTIS(J)=SHORT TERM INTEGRATED PASTURE SOIL ACTIVITY (BQ-D/KG)
      PARAMETER (MAXP=4,NMAX=32)
*
*     Identification
*     Program Name: COMIDA
*     Module Name: short.f Version 1.2
*     Date: 1/19/93 Time: 10:32:42
*
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C COMPAR.BLK
      COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
```

```
      DIMENSION ALPHA(7)
      DIMENSION A(NMAX),B(NMAX),QSTIP(MAXP),QSTIS(MAXP)
      Character idkeyw*72
      Data idkeyw /'@(#)short.f         1.2  1/19/93  10:32:42\0'/
      idkeyw = idkeyw
C     substitue A matrix values to matrix B
      DO 10,I = 1,NMAX
       B(I) = A(I)
 10    CONTINUE
        X1 = 0.0
C     check the value of TINTM to make sure it does not exceed the live
C     stock grazing time
      IF(TINTM.GE.(TEL-TSL))THEN
        WRITE(*,*) 'ERROR - TINTM CANNOT BE GREATER THAN TEL-TSL'
        PAUSE
        RETURN
      ENDIF

C     Condition 1: TI is less than TSL
      IF(TI.LE.TSL)THEN
        T = TINTM - (TSL-TI)
        IF(T.LE.0.0)THEN
         DO 20,J = 1,NM
          QSTIP(J) = 0.0
          QSTIS(J) = 0.0
 20       CONTINUE
         RETURN
        ENDIF
C        now integrate the pasture concentration
        CALL RK4SOLVE(B,X1,T,NM)
        GOTO 999
      ENDIF

C     Condition 2: TI is greater than TSL and TI + TINTM less than TEL
      IF(TI.GT.TSL.AND.(TI + TINTM).LT.TEL)THEN
        T = TINTM
        CALL RK4SOLVE(B,X1,T,NM)
        GOTO 999
      ENDIF

C     Condition 3: TI is greater than TEL
      IF(TI.GE.TEL)THEN
         DO 40,J = 1,NM
          QSTIP(J) = 0.0
          QSTIS(J) = 0.0
 40       CONTINUE
         RETURN
      ENDIF

C     Condition 4: TI is greater than TSL and less than TEL
C                TI + TINTM greater than TEL
      IF(TI.GT.TSL.AND.TI.LT.TEL.AND.(TI + TINTM).GT.TEL)THEN
        T = TEL-TI
        CALL RK4SOLVE(B,X1,T,NM)
      ENDIF

C     set value of QSTIP for return to PASTURE1
 999  DO 30, J = 1,NM
        QSTIP(J) = (B(6 + (J-1)*8) + B(8 + (J-1)*8))
        QSTIS(J) = B(7 + (J-1)*8)/(PSS*XS)
 30   CONTINUE
      WRITE(4,1000) T,(QSTIP(J),J = 1,MAXP),(QSTIS(J),J = 1,MAXP)

 1000 FORMAT(1X,'STORT TERM PASTURE INTEGRATION TIME ',1PE9.2
     !/,1X,'SHORT TERM INT PASTURE Bq-d/kg',1PE9.2,1PE9.2,1PE9.1,1PE9.2
     !/,1X,'SHRT INT PASTURE SOIL  Bq-d/kg',1PE9.2,1PE9.2,1PE9.1,1PE9.2)
      RETURN
      END
C ******************************
C *  SUBROUTINE POULTRY         *
C ******************************
      SUBROUTINE POULTRY(NM,QTIG,QIPS,QTIL)
C This subroutine calculates the integrated activity in poultry for any year
C intake of contaminated hay pasture or grain
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (MAXP = 4)
*
```

```
*     Identification
*     Program Name: COMIDA
*     Module Name: poultry.f Version 1.3
*     Date: 1/19/93 Time: 11:24:34
*
C NUCPAR1.BLK
      COMMON /NUCPAR1/NMEMBER,NPROG,THALF,ZKL
      DIMENSION THALF(MAXP),ZKL(MAXP)
C POULPAR.BLK
      COMMON /POULPAR/RGPL,RSPL,RLPL
C POULNUC.BLK
      COMMON /POULNUC/TCPL,TCO
      DIMENSION TCPL(MAXP),TCO(MAXP)
C POULSTAT.BLK
      COMMON /POULSTATE/QIPLG,QIPLS,QIPLL,QTIPL,TQP
      DIMENSION QIPLG(MAXP),QIPLS(MAXP),QTIPL(MAXP),QIPLL(MAXP),
     !TQP(MAXP)
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
      DIMENSION QTIG(MAXP),QIPS(MAXP),QTIL(MAXP),D(MAXP)
      Character idkeyw*72
      Data idkeyw /'@(#)poultry.f        1.3  1/19/93  11:24:34\0'/
      idkeyw = idkeyw
C     Calculate contribution from grain, soil, legumes and total
C     Store accumulated total integrated value in TQP
C     Set decay rate constant array such that decay is only accounted
C     for with parent nuclides.
      DO 5,J = 1,NM
        D(J) = 0.0
 5    CONTINUE
      D(1) = LOG(2.)/THALF(1)
      DO 10,J = 1,NM
        QIPLG(J) = QTIG(J)*RGPL*TCPL(J)*EXPF(-D(J)*THPOL)
        QIPLS(J) = QIPS(J)*RSPL*TCPL(J)*EXPF(-D(J)*THPOL)
        QIPLL(J) = QTIL(J)*RLPL*TCPL(J)*EXPF(-D(J)*THPOL)
        QTIPL(J) = (QIPLG(J) + QIPLS(J) + QIPLL(J))
        TQP(J) = TQP(J) + QTIPL(J)
 10   CONTINUE
      RETURN
      END
C ******************************
C *  SUBROUTINE OTHER          *
C ******************************
      SUBROUTINE OTHER(NM,QTIG,QIPS,QTIL,QTIH,QTIP)
C This subroutine calculates the integrated activity in poultry for any year
C intake of contaminanted hay pasture or grain
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (MAXP = 4)
*
*     Identification
*     Program Name: COMIDA
*     Module Name: other.f Version 1.2
*     Date: 1/19/93 Time: 10:34:32
*
C OTHERPAR.BLK
      COMMON /OTHERPAR/RGO,RSO,RLO,RHHO,RPO
C POULNUC.BLK
      COMMON /POULNUC/TCPL,TCO
      DIMENSION TCPL(MAXP),TCO(MAXP)
C OTHERSTA.BLK
      COMMON /OTHERSTATE/QIOG,QIOS,QTIO,QIOP,QIOL,QIOH,TQO
      DIMENSION QIOG(MAXP),QIOS(MAXP),QTIO(MAXP),QIOP(MAXP),QIOH(MAXP),
     !QIOL(MAXP),TQO(MAXP)
C NUCPAR1.BLK
      COMMON /NUCPAR1/NMEMBER,NPROG,THALF,ZKL
      DIMENSION THALF(MAXP),ZKL(MAXP)
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C     state variables
      DIMENSION QTIG(MAXP),QIPS(MAXP),QTIL(MAXP),QTIH(MAXP),QTIP(MAXP),
     !D(MAXP)
      Character idkeyw*72
      Data idkeyw /'@(#)other.f        1.2  1/19/93  10:34:32\0'/
      idkeyw = idkeyw
C     Calculate contribution from grain, soil, legume, hay and pasture and total
```

```
C     Store total in TQO
C     Set decay rate constant array such that decay is only accounted
C     for with parent nuclides.
      DO 5,J = 1,NM
        D(J) = 0.0
 5    CONTINUE
      D(1) = LOG(2.)/THALF(1)
      DO 10,J = 1,NM
        QIOG(J) = QTIG(J)*RGO*TCO(NM)*EXPF(-D(J)*THOTHER)
        QIOS(J) = QIPS(J)*RSO*TCO(NM)*EXPF(-D(J)*THOTHER)
        QIOL(J) = QTIL(J)*RLO*TCO(NM)*EXPF(-D(J)*THOTHER)
        QIOH(J) = QTIH(J)*RHHO*TCO(NM)*EXPF(-D(J)*THOTHER)
        QIOP(J) = QTIP(J)*RPO*TCO(NM)*EXPF(-D(J)*THOTHER)
        QTIO(J) = (QIOG(J) + QIOS(J) + QIOL(J) + QIOH(J) + QIOP(J))
        TQO(J) = TQO(J) + QTIO(J)
 10   CONTINUE
      RETURN
      END
C ******************************
C *  SUBROUTINE FALLOUT        *
C ******************************
      SUBROUTINE FALLOUT(FV,FS,BSTART,BSTAND,TIME,ZKG,ALPHA)
      IMPLICIT REAL*8 (A-H,O-Z)
*
*     Identification
*     Program Name: COMIDA
*     Module Name: fallout.f Version 1.2
*     Date: 1/19/93  Time: 10:35:30
*
C this subroutine calculates the standing biomass at accident time
C and the fration of fallout on the vegetative and soil surface
C FV = FRATION OF FALLOUT TO VEG
C FS = FRACTION OF FALLOUT TO SOIL
C BSTART = INITIAL BIOMASS (KG/M2 dry)
C BSTAND = MAXIMUM STANDING BIOMASS (KG/M2 dry)
C TGROW = TIME REMAINING IN GROWING SEASON (d)
C B = CURRENT BIOMASS (KG)
      Character idkeyw*72
      Data idkeyw /'@(#)fallout.f         1.2  1/19/93  10:35:30\0'/
      idkeyw = idkeyw
      A = LOG((BSTAND-BSTART)/BSTART)
      B = BSTAND/(1 + EXP(A-ZKG*TIME))
      B = BSTAND/(1 + EXPF(A-ZKG*TIME))
      FS = EXPF(-ALPHA*B)
      FV = 1-FS
      WRITE(4,1000) B,FV,FS
 1000 FORMAT(1X,'BIOMASS AT TIME OF ACCIDENT           ',1PE9.2
     !/,1X,'FRACTION OF FALLOUT TO VEG SURFACE     ',1PE9.2
     !/,1X,'FRACTION OF FALLOUT TO SOIL SURFACE    ',1PE9.2)

      RETURN
      END

C ******************************
C *  SUBROUTINE ONEYEAR        *
C ******************************
      SUBROUTINE ONEYEAR(NM,NUC,TGROWP,CUTOFF,NCUTOFF)
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*6 NUC
      PARAMETER (MAXP = 4,NCR = 5,NCUTMAX = 3)
C TGROW = REMAINING TIME OF GROWING SEASON AFTER ACCIDENT (d)
C TGROWH = REMAINING TIME IN CURRENT HAY GROWING SEASON AFTER ACCIDENT (d)
C TGROWP = REMAINING TIME IN PASTURE SEASON (d)
C KCUT = HAY GROWING SEASON WHEN ACCIDENT OCCURED
*
*     Identification
*     Program Name: COMIDA
*     Module Name: oneyear.f Version 1.2
*     Date: 1/19/93  Time: 10:36:36
*
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C HAYPAR.BLK
      COMMON /HAYPAR/ZKGH,BIH,BMAXH,NCUT,TCUT
      DIMENSION TCUT(0:NCUTMAX)
C NUCPAR1.BLK
```

```
      COMMON /NUCPAR1/NMEMBER,NPROG,THALF,ZKL
      DIMENSION THALF(MAXP),ZKL(MAXP)
C COMPAR.BLK
      COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
      DIMENSION ALPHA(7)
C PLANT.BLK
      COMMON /PLANT/ ZKG,CR,THICK,RHO,BMAX,BSTART,GTIME
      DIMENSION CR(MAXP)
      COMMON /RCONTANTS/ Z12,Z16,Z21,Z23,Z34,Z3,Z43,D,Z52
      DIMENSION D(MAXP),Z15(MAXP),Z3(MAXP),NUC(MAXP)
      DIMENSION QTIG(MAXP),QTIP(MAXP),QIPS(MAXP),QTIH(MAXP),QTIL(MAXP),
     ! QSTIP(MAXP)
      Character idkeyw*72
      Data idkeyw /'@(#)oneyear.f       1.2  1/19/93  10:36:36\0'/
      idkeyw = idkeyw
C     set fixed values for RCONSTANT common block, RCONSTANT passes the
C     values of the rate constants to the DERIVES subroutine
      WRITE(4,1000)
      NY = 1
      NM = NMEMBER
      THICK = XR
      RHO = PSR
      Z23 = ZKP
      Z34 = ZKAD
      Z43 = ZKDE
C     assign nuclide specific values for leach rate (Z3) and decay constant (D)
      DO 10,J = 1,NMEMBER
        Z3(J) = ZKL(J)
        D(J) = LOG(2.)/THALF(J)
 10   CONTINUE
C     Assign a value to TGROW for crops.  TGROW>0 for an accident that occurs
C     during the growing season. TGROW<0 for an accident that occurs outside
C     the growing season.
      IF(TI.GE.TSC.AND.TI.LT.TEC)THEN
        TGROW = TEC-TI
        ELSE
        TGROW = -1.0
      ENDIF
C     Assign a value to TGROWH for hay.  TGROWH>0 for an accident that occurs
C     during the hay growing season. TGROWH<0 for an accident that occurs
C     outside the hay growing season.  Define KCUT as the growing season the
C     accident occured on.
      IF(TI.GE.TSH.AND.TI.LT.TCUT(NCUT))THEN
         DUMMY = TSH
         DO 20, I = 1,NCUT
           IF(TI.LT.TCUT(I).AND.TI.GE.DUMMY)THEN
             KCUT = I
             TGROWH = TCUT(I)-TI
             DUMMY = TCUT(I)
           ENDIF
 20      CONTINUE
        ELSE
          TGROWH = -1.0
      ENDIF
C     Assign value to TGROWP.  If TGROWP>0 then accident occured during the
C     the growing season
      IF(TI.GE.TSP.AND.TI.LT.TEL)THEN
        TGROWP = TEL-TI
         ELSE
          TGROWP = -1.0
      ENDIF

      CALL PASTURE1(TGROWP,NM,QTIP,QIPS,QSTIP,QSTIS)

C For crop and hay, the timing of the accident must be accouted for.
C Time T1 is the time animal feed inventories are consumed over.

C ****************************************************************
C *  CASE 1. ACCIDENT OCCURS DURING OR BEFOR ANNUAL GROWING SEASON  *
C ****************************************************************

      IF(TI.LT.TEC)THEN
        T1 = 365-(THGL + TEC) + TI
        CALL CROP1(TGROW,NM,QTIG,QTIL,T1)
      ENDIF
      IF(TI.LT.TCUT(NCUT))THEN
       T1 = 365-(THHAY + TCUT(NCUT)) + TI
```

```
      CALL HAY1(TGROWH,NM,KCUT,QTIH,T1)
     ENDIF

C *******************************************************
C *  CASE 2. ACCIDENT OCCURS AFTER ANNUAL GROWING SEASON AND *
C *  AFTER HOLDUP PERIOD                                  *
C *******************************************************
     IF(TI.GT.(TEC+THGL))THEN
       CALL CROP1(TGROW,NM,QTIG,QTIL,T1)
       T1=TI-(THGL+TEC)
       T2=0.
       CALL CROPN(NM,QTIG,QTIL,T1,T2)
     ENDIF
     IF(TI.GT.(TCUT(NCUT)+THHAY))THEN
      CALL HAY1(TGROWH,NM,KCUT,QTIH,T1)
      T1=TI-(THHAY+TCUT(NCUT))
      T2=0.0
      CALL HAYN(NM,QTIH,T1,T2)
     ENDIF

C *******************************************************

C *  CASE 3. ACCIDENT OCCURS AFTER ANNUAL GROWING SEASON AND *
C *  DURING HOLD-UP PERIOD                                *
C *******************************************************
C First year concentrations are zero because animal feeds grown
C during the accident year will not be consumed.  T1 is set to a
C small value so the accident years inventories are saved for subsequent years.
     IF(TI.GE.TEC.AND.TI.LE.(TEC+THGL))THEN
       CALL CROP1(TGROW,NM,QTIG,QTIL,T1)
       T1=(TEC+THGL)-TI
       IF(T1.LE.0.)THEN
        T1=0.01
       ENDIF
       T2=0.0
       CALL CROPN(NM,QTIG,QTIL,T1,T2)
C       zero current year inventories
       DO 30, J=1,NM
        QTIG(J)=0.0
        QTIL(J)=0.0
 30    CONTINUE
     ENDIF

     IF(TI.GE.TCUT(NCUT).AND.TI.LE.(TCUT(NCUT)+THHAY))THEN
      CALL HAY1(TGROWH,NM,KCUT,QTIH,T1)
      T1=(THHAY+TCUT(NCUT))-TI
      IF(T1.LE.0.)THEN
       T1=0.01
      ENDIF
      T2=0.0
      CALL HAYN(NM,QTIH,T1,T2)
C      Zero the current year integrated inventories
      DO 40, J=1,NM
       QTIH(J)=0.0
 40   CONTINUE
     ENDIF
     CALL BEEF(NM,QTIG,QTIL,QTIH,QTIP,QIPS)
     CALL MILK(NM,QTIG,QTIH,QTIP,QIPS,QTIL,QSTIP,QSTIS,NY)
     CALL POULTRY(NM,QTIG,QIPS,QTIL)
     CALL OTHER(NM,QTIG,QIPS,QTIL,QTIH,QTIP)
     CALL WOUT(NY,QTIG,QTIL,QTIH,QTIP,QIPS,NUC,CUTOFF,NCUTOFF)
 1000 FORMAT(1X,'RESULTS FOR 1ST YEAR (YEAR OF ACCIDENT)')
     RETURN
     END

C ******************************
C *  SUBROUTINE NYEAR          *
C ******************************
     SUBROUTINE NYEAR(NM,NY,KFLAG,NUC,TGROWP,CUTOFF,NCUTOFF)
     IMPLICIT REAL*8 (A-H,O-Z)
     PARAMETER (MAXP=4,NCUTMAX=3)
     CHARACTER*6 NUC
     DIMENSION QTIP(MAXP),QTIH(MAXP),QTIG(MAXP),QIPS(MAXP),QTIL(MAXP)
     DIMENSION NUC(MAXP),DUMMY1(MAXP),DUMMY2(MAXP)
*
*    Identification
*    Program Name: COMIDA
```

```
*    Module Name: nyear.f Version 1.2
*    Date: 1/19/93 Time: 10:39:41
*
C TIMEPAR.BLK
     COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
    I THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
C HAYPAR.BLK
     COMMON /HAYPAR/ZKGH,BIH,BMAXH,NCUT,TCUT
     DIMENSION TCUT(0:NCUTMAX)
     Character idkeyw*72
     Data idkeyw /'@(#)nyear.f         1.2  1/19/93  10:39:41\0'/
     idkeyw = idkeyw
     WRITE(4,1000) NY
     WRITE(*,1000) NY
C    Check if cutoff time is exceeded. If so, then do not proceed with calc.
     IF(FLOAT(NY).GT.CUTOFF)THEN
       IF(KFLAG.EQ.1)THEN
         CALL WOUT(NY,QTIG,QTIL,QTIH,QTIP,QIPS,NUC,CUTOFF,NCUTOFF)
       ENDIF
       RETURN
     ENDIF
C    Dummy variables are place holders for the first year pasture and pasture
C    and pasture soil inventories integrated for time TINTM.
C    These values are not used in subsequent years calculations.
     DO 10,J = 1,NM
      DUMMY1(J) = 0.
      DUMMY2(J) = 0.
 10   CONTINUE
     CALL PASTUREN(TGROWP,NM,QTIP,QIPS)
C *****************************************************************
C *  CASE 1. ACCIDENT OCCURS DURING OR BEFOR ANNUAL GROWING SEASON  *
C *****************************************************************

     IF(TI.LT.TEC)THEN
       T1 = 365-(THGL + TEC) + TI
       T2 = (TEC + THGL)-TI
       CALL CROPN(NM,QTIG,QTIL,T1,T2)
     ENDIF

     IF(TI.LT.TCUT(NCUT))THEN
      T1 = 365-(THHAY + TCUT(NCUT)) + TI
      T2 = (TCUT(NCUT) + THHAY)-TI
      CALL HAYN(NM,QTIH,T1,T2)
     ENDIF

C ***********************************************************
C *  CASE 2. ACCIDENT OCCURS AFTER ANNUAL GROWING SEASON AND *
C *  AFTER HOLDUP PERIOD                                     *
C ***********************************************************
     IF(TI.GT.(TEC + THGL))THEN
       T1 = TI-(THGL + TEC)
       T2 = 365-TI + (THGL + TEC)
       CALL CROPN(NM,QTIG,QTIL,T1,T2)
     ENDIF
     IF(TI.GT.(TCUT(NCUT) + THHAY))THEN
      T1 = TI-(THHAY + TCUT(NCUT))
      T2 = (TCUT(NCUT) + THHAY)-TI
      CALL HAYN(NM,QTIH,T1,T2)
     ENDIF

C ************************************************************
C *  CASE 3. ACCIDENT OCCURS AFTER ANNUAL GROWING SEASON AND  *
C *  DURING HOLD-UP PERIOD                                    *
C ************************************************************
C First year concentrations are zero because animal feeds grown
C during the accident year will not be consumed.  T1 is set to a
C small value so the accident years inventories are saved for subsequent years.
     IF(TI.GE.TEC.AND.TI.LE.(TEC + THGL))THEN
       T1 = 0.001
       T2 = 365-((THGL + TEC)-TI)
       CALL CROPN(NM,QTIG,QTIL,T1,T2)
     ENDIF

     IF(TI.GE.TCUT(NCUT).AND.TI.LE.(TEC + THHAY))THEN
      T1 = 0.001
      T2 = 365-((THHAY + TCUT(NCUT))-TI)
      CALL HAYN(NM,QTIH,T1,T2)
```

```
      ENDIF
C *************************************************************
      CALL BEEF(NM,QTIG,QTIL,QTIH,QTIP,QIPS)
      CALL MILK(NM,QTIG,QTIH,QTIP,QIPS,QTIL,DUMMY1,DUMMY2,NY)
      CALL POULTRY(NM,QTIG,QIPS,QTIL)
      CALL OTHER(NM,QTIG,QIPS,QTIL,QTIH,QTIP)
      IF(KFLAG.EQ.1)THEN
        CALL WOUT(NY,QTIG,QTIL,QTIH,QTIP,QIPS,NUC,CUTOFF,NCUTOFF)
      ENDIF
 1000 FORMAT(5X,'RESULTS FOR FOR YEAR ',I2)
      RETURN
      END
C ******************************
C *  SUBROUTINE WOUT          *
C ******************************
      SUBROUTINE WOUT(NY,QTIG,QTIL,QTIH,QTIP,QIPS,NUC,CUTOFF,NCUTOFF)
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (MAXP=4,NMAX=32,NCR=5)
      CHARACTER*6 NUC
      CHARACTER*9 SPC
*
*     Identification
*     Program Name: COMIDA
*     Module Name: wout.f Version 1.6
*     Date: 1/19/93  Time: 11:29:29
*
C CROPNUC.BLK
      COMMON /CROPNUC/CRC,ZKABC
      DIMENSION CRC(NCR,MAXP),ZKABC(NCR,MAXP)
C HAYNUC.BLK
      COMMON /HAYNUC/CRH,ZKABH
      DIMENSION CRH(MAXP),ZKABH(MAXP)
C PASTNUC.BLK
      COMMON /PASTNUC/CRP,ZKABP
      DIMENSION CRP(MAXP),ZKABP(MAXP)
C CROPSTAT.BLK
      COMMON /CROPSTATE/QVSC,QSSC,QRSC,QVIC,QFSC,TQC,QTIC,CTOTAL
      DIMENSION QVSC(NCR,MAXP),QSSC(NCR,MAXP),QRSC(NCR,MAXP)
     I,QVIC(NCR,MAXP),QFSC(NCR,MAXP),TQC(NCR,MAXP),QTIC(NCR,MAXP)
     I,CTOTAL(NCR+2,MAXP)
C PASTSTAT.BLK
      COMMON /PASTSTATE/QVSP,QSSP,QRSP,QVIP,QFSP
      DIMENSION QVSP(MAXP),QSSP(MAXP),QRSP(MAXP),QVIP(MAXP)
     I,QFSP(MAXP)
C HAYSTATE.BLK
      COMMON /HAYSTATE/QVSH,QSSH,QRSH,QVIH,QFSH
      DIMENSION QVSH(MAXP),QSSH(MAXP),QRSH(MAXP),QVIH(MAXP)
     I,QFSH(MAXP)
C NUCPAR1.BLK
      COMMON /NUCPAR1/NMEMBER,NPROG,THALF,ZKL
      DIMENSION THALF(MAXP),ZKL(MAXP)
C BEEFNUC.BLK
      COMMON /BEEFNUC/TCB,TCM
      DIMENSION TCB(MAXP),TCM(MAXP)
C POULNUC.BLK
      COMMON /POULNUC/TCPL,TCO
      DIMENSION TCPL(MAXP),TCO(MAXP)
C BEEFSTAT.BLK
      COMMON /BEEFSTATE/QIBP,QIBH,QIBG,QIBS,QIBT,QIBL,TQB
      DIMENSION QIBP(MAXP),QIBH(MAXP),QIBG(MAXP),QIBS(MAXP),QIBT(MAXP)
     I,QIBL(MAXP),TQB(MAXP)
C MILKSTAT.BLK
      COMMON /MILKSTATE/QIMP,QIMH,QIMG,QIMS,QIMT,QIML,QISM,TQM
      DIMENSION QIMP(MAXP),QIMH(MAXP),QIMG(MAXP),QIMS(MAXP),QIMT(MAXP)
     I,QIML(MAXP),QISM(MAXP),TQM(MAXP)
C MILKPAR.BLK
      COMMON /MILKPAR/RPM,RHM,RGM,RSM,RLM
C POULSTAT.BLK
      COMMON /POULSTATE/QIPLG,QIPLS,QIPLL,QTIPL,TQP
      DIMENSION QIPLG(MAXP),QIPLS(MAXP),QTIPL(MAXP),QIPLL(MAXP),
     ITQP(MAXP)
C OTHERSTA.BLK
      COMMON /OTHERSTATE/QIOG,QIOS,QTIO,QIOP,QIOL,QIOH,TQO
      DIMENSION QIOG(MAXP),QIOS(MAXP),QTIO(MAXP),QIOP(MAXP),QIOH(MAXP),
     IQIOL(MAXP),TQO(MAXP)
C COMPAR.BLK
      COMMON /COMPAR/ZKP,ZKW,ZKR,ZKRS,ZKAD,ZKDE,PSS,PSR,XR,XS,ALPHA
```

```
      DIMENSION ALPHA(7)
C TIMEPAR.BLK
      COMMON /TIMEPAR/TT,TSC,TSP,TSL,TSH,TEC,TEL,TI,TINTM,
     ! THBEEF,THMILK,THPOL,THOTHER,THGL,THHAY
      DIMENSION NUC(MAXP)
      DIMENSION QTIG(MAXP),QTIL(MAXP),QTIP(MAXP),QIPS(MAXP),QTIH(MAXP)
      Character idkeyw*72
      Data idkeyw /'@(#)wout.f        1.6 1/19/93 11:29:29\0'/
      idkeyw = idkeyw
      SPC = ' —  '
C     NY = the year of the simulation, if year 1 the print nuclide spec data
C     NCUTOFF = THE NUMBER OF HALFLIVES TO CUTOFF
      IF(NY.EQ.1)THEN
        WRITE(3,500) ZKAD,ZKDE,NCUTOFF,CUTOFF
        DO 40,J = 1,NMEMBER
          WRITE(3,1000) J,NUC(J),THALF(J),ZKL(J),(CRC(I,J),I = 1,NCR),
     !    CRH(J),CRP(J),(ZKABC(I,J),I = 1,NCR),ZKABH(J),ZKABP(J),
     !    TCB(J),TCM(J),TCPL(J),TCO(J)
 40     CONTINUE
      ENDIF
      IF(FLOAT(NY).GT.CUTOFF.AND.NY.NE.1)THEN
        DO 42,I = 1,NCR
          DO 43,J = 1,NMEMBER
            QVSC(I,J) = 0.0
            QSSC(I,J) = 0.0
            QRSC(I,J) = 0.0
            QFSC(I,J) = 0.0
            QVIC(I,J) = 0.0
            CTOTAL(I,J) = 0.0
 43       CONTINUE
 42     CONTINUE
        DO 44, J = 1,NMEMBER
          QTIG(J) = 0.0
          QTIH(J) = 0.0
          QTIL(J) = 0.0
          QTIP(J) = 0.0
          QIPS(J) = 0.0
          QIBG(J) = 0.0
          QIBH(J) = 0.0
          QIBL(J) = 0.0
          QIBP(J) = 0.0
          QIBS(J) = 0.0
          QIBT(J) = 0.0
          QIMG(J) = 0.0
          QIMH(J) = 0.0
          QIML(J) = 0.0
          QIMP(J) = 0.0
          QIMS(J) = 0.0
          QIMT(J) = 0.0
          QIPLG(J) = 0.0
          QIPLL(J) = 0.0
          QIPLS(J) = 0.0
          QTIPL(J) = 0.0
          QIOG(J) = 0.0
          QIOH(J) = 0.0
          QIOL(J) = 0.0
          QIOP(J) = 0.0
          QIOS(J) = 0.0
          QTIO(J) = 0.0
 44     CONTINUE
      ENDIF
      WRITE(3,2000) NY
      DO 50,J = 1,NMEMBER
        WRITE(3,3000) J,(QVSC(I,J),I = 1,NCR),(QSSC(I,J),I = 1,NCR),
     ! (QRSC(I,J),I = 1,NCR),(QFSC(I,J),I = 1,NCR),(QVIC(I,J),I = 1,NCR),
     ! (CTOTAL(I,J),I = 1,NCR),(TQC(I,J),I = 1,NCR)
        WRITE(3,4000) QTIG(J),QTIH(J),QTIL(J),QTIP(J),QIPS(J),SPC,SPC,
     ! QIBG(J),QIBH(J),QIBL(J),QIBP(J),QIBS(J),QIBT(J),TQB(J),
     ! QIMG(J),QIMH(J),QIML(J),QIMP(J),QIMS(J),QIMT(J),TQM(J),
     ! QIPLG(J),SPC,QIPLL(J),SPC,QIPLS(J),QTIPL(J),TQP(J),
     ! QIOG(J),QIOH(J),QIOL(J),QIOP(J),QIOS(J),QTIO(J),TQO(J)
        IF(NY.EQ.1)THEN
          WRITE(3,5000) TINTM,QISM(J)
        ENDIF
 50   CONTINUE

 500 FORMAT(1X,'SOIL ADSORPTION RATE CONSTANT (d**-1) ',1PE9.2
```

```
     !/,1X,'SOIL DESORPTION RATE CONSTANT (d**-1) ',1PE9.2
     !/,1X,'NUMBER OF HALF LIVES TO CUTOFF      ',I3
     !/,1X,'CUTOFF TIME (years)                ',1PE9.2)


1000 FORMAT(1X,'--------------------------------'
     !/,1X,'DATA FOR MEMBER #',I2,1X,a8,1X,'HALF LIFE (d) ',1PE10.3,2X,'
     !LEACH RATE (d**-1) ',1PE9.2
     !/,4X,'CROP TYPE >>>',8X,'GRAINS  LEAF VEG ROOT    FRUITS  LEGUM
     !ES  HAY     PASTURE'
     !/,1X,'CONCENTRATION RATIO   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,
     ! 1PE9.2,1PE9.2
     !/,1X,'FOLIAR ABSORPTION     ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,
     ! 1PE9.2,1PE9.2
     !/,1X,'   ANIMAL PRODUCT >>>  BEEF (d/kg) MILK (d/L)  POUL (d/kg)
     !OTHER (d/kg)'
     !/,1X,'TRANSFER COEFFICIENT  ',1PE9.2,3X,1PE9.2,3X,1PE9.2,3X,1PE9.
     !2
     !/,10X)

2000  FORMAT(1X,'=============== RESULTS FOR ACCIDENT YEAR NUMBER ',I2,'
     !==================')

3000 FORMAT(1X,'RESULTS FOR MEMBER # ',I2,1X,'GRAINS  LEAF VEG   ROOT
     !  FRUITS  LEGUMES'
     !/,1X,'                  ______________________________
     !______'
     !/,1X,'VEGETATION SURF (Bq/kg)',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'SURFACE SOIL (Bq/m**2) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'LABILE SOIL (Bq/m**2)  ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'FIXED SOIL (Bq/m**2)   ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'VEGETATION INT (Bq/kg) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'VEGETATION TOT (Bq/kg) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'CUMULAT TOT+ (Bq-d/kg) ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2
     !/,1X,'--------------')


4000 FORMAT(1X,'INTEGRATED ANIMAL PRODUCT AND FEED INVENTORIES++ (Bq-d/
     !kg)'
     !/,17X,'GRAIN    HAY    LEGUME  PASTURE  SOIL    TOTAL  CUMULA
     !TIVE '
     !/,17X,'_____________________________________________________
     !____'
     !/,' ANIMAL FEED    ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,a9,a9
     !/,' BEEF           ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,
     !1PE9.2
     !/,' MILK (Bq-d/L)  ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,
     !1PE9.2
     !/,' POULTRY        ',1PE9.2,a9,1PE9.2,a9,1PE9.2,1PE9.2,1PE9.2
     !/,' OTHER          ',1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,
     !1PE9.2
     !/,1X,'--------------')

5000 FORMAT(1X,F4.0,' DAY INTEGRATED MILK CONCENTRATION FROM PASTURE (B
     !q-d/L): ',1PE9.2)


999  RETURN
     END
C *******************************
C *  SUBROUTINE RK4SOLVE      *
C *******************************
     SUBROUTINE RK4SOLVE(A,X1,X2,NM)
C this subroutine sets up the varaibles to solve the ODE's with initial values
C given in the array A and beginning and ending times X1 and X2 for NMEMBER*8
C number of variables to the accuracy defined by EPS.
C New values are returned in the A array.

     IMPLICIT REAL*8 (A-H,O-Z)
     PARAMETER (NMAX=32,MAXP=4,EPS=1.0E-6)
     DIMENSION A(NMAX),Y(NMAX),D(MAXP),Z3(MAXP),Z15(MAXP)
*
*    Identification
*    Program Name: COMIDA
*    Module Name: rk4solve.f Version 1.2
*    Date: 1/19/93 Time: 10:41:45
*
```

```
      COMMON /PATH/ KMAX,KOUNT,DXSAV,XP(200),YP(NMAX,200)
      COMMON /RCONTANTS/ Z12,Z15,Z21,Z23,Z34,Z3,Z43,D,Z52
      Character idkeyw*72
      Data idkeyw /'@(#)rk4solve.f       1.2  1/19/93  10:41:45\0'/
      idkeyw = idkeyw
C X1 = begin time
C X2 = end time
      NVAR = 8*NM
C convert activity from Bq to number of atoms. Rate constants in d-1
C coversion factor = 86400 seconds per day
       N = 1
       M = 0
       DO 10 J = 1,NM
         DO 20,K = 1,8
           Y(K + M) = A(K + M)/(D(N)/86400.)
 20        CONTINUE
         N = N + 1
         M = M + 8
 10    CONTINUE
C set integration values
      DXSAV = 1.0
      KMAX = 0
      H1 = 2.5
      HMIN = 1.E-20
C solve those guys!!!!!!!!!!!!!!!
       CALL ODEINT(Y,NVAR,X1,X2,EPS,H1,HMIN,NOK,NBAD)
c convert to activity
       N = 1
       M = 0
       DO 30 J = 1,NM
        DO 40,K = 1,8
          A(K + M) = Y(K + M)*(D(N)/86400.)
 40       CONTINUE
        N = N + 1
        M = M + 8
 30    CONTINUE
      RETURN
      END

C ******************************
C *    SUBROUTINE DERIVES     *
C ******************************
      SUBROUTINE DERIVS(NVAR,TIME,Y,DYDT)

      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NMAX = 32,TINY = 1.E-30,MAXP = 4)
      COMMON /PATH/ KMAX,KOUNT,DXSAV,XP(200),YP(NMAX,200)
      COMMON /RCONTANTS/ Z12,Z15,Z21,Z23,Z34,Z3,Z43,D,Z52
C PLANT.BLK
      COMMON /PLANT/ ZKG,CR,THICK,RHO,BMAX,BSTART,GTIME
      DIMENSION CR(MAXP)
      DIMENSION Y(NMAX),D(MAXP),Z3(MAXP),DYDT(NMAX),Z35(MAXP)
      DIMENSION Z15(MAXP)

C light and temperature modification to plant growth model not considered,
C calculate the root uptake rate constant for each progeny
      NP = NVAR/8
      DO 10,I = 1,NP
        A = LOG((BMAX-BSTART)/BSTART)
        B = BMAX/(1 + EXP(A-ZKG*(TIME + GTIME)))
        DBDT = ZKG*B*(BMAX-B)/BMAX
        Z35(I) = DBDT*CR(I)/(THICK*RHO)
 10   CONTINUE
C  COMIDA derivitives
C the integrated compartments 6 and 8 are divided by the current biomass

      DYDT(1) = Z21*Y(2)-(Z12 + Z15(1) + D(1))*Y(1)
      DYDT(2) = Z12*Y(1) + Z52*Y(5)-(Z21 + D(1) + Z23)*Y(2)
      DYDT(3) = Z23*Y(2) + Z43*Y(4)-(Z34 + Z35(1) + Z3(1) + D(1))*Y(3)
      DYDT(4) = Z34*Y(3)-(Z43 + D(1))*Y(4)
      DYDT(5) = Z35(1)*Y(3) + Z15(1)*Y(1)-D(1)*Y(5)-Z52*Y(5)
      DYDT(6) = Y(1)/B
      DYDT(7) = Y(2)
      DYDT(8) = Y(5)/B

      DYDT(9) = D(1)*Y(1) + Z21*Y(10)-(Z12 + Z15(2) + D(2))*Y(9)
      DYDT(10) = D(1)*Y(2) + Z12*Y(9) + Z52*Y(13)-(Z21 + D(2) + Z23)*Y(10)
```

```
      DYDT(11)=D(1)*Y(3)+Z23*Y(10)+Z43*Y(12)-(Z34+Z35(2)+Z3(2)+D(2))
     ! *Y(11)
      DYDT(12)=D(1)*Y(4)+Z34*Y(11)-(Z43+D(2))*Y(12)
      DYDT(13)=D(1)*Y(5)+Z35(2)*Y(11)+Z15(2)*Y(9)-D(2)*Y(13)-Z52*Y(13)
      DYDT(14)=Y(9)/B
      DYDT(15)=Y(10)
      DYDT(16)=Y(13)/B

      DYDT(17)=D(2)*Y(9)+Z21*Y(18)-(Z12+Z15(3)+D(3))*Y(17)
      DYDT(18)=D(2)*Y(10)+Z12*Y(17)+Z52*Y(21)-(Z21+D(3)+Z23)*Y(18)
      DYDT(19)=D(2)*Y(11)+Z23*Y(18)+Z43*Y(20)-(Z34+Z35(3)+Z3(3)+D(3))
     ! *Y(19)
      DYDT(20)=D(2)*Y(12)+Z34*Y(19)-(Z43+D(3))*Y(20)
      DYDT(21)=D(2)*Y(13)+Z35(3)*Y(19)+Z15(3)*Y(17)-(D(3)+Z52)*Y(21)
      DYDT(22)=Y(17)/B
      DYDT(23)=Y(18)
      DYDT(24)=Y(21)/B

      DYDT(25)=D(3)*Y(17)+Z21*Y(26)-(Z12+Z15(4)+D(4))*Y(25)
      DYDT(26)=D(3)*Y(18)+Z12*Y(25)+Z52*Y(29)-(Z21+D(4)+Z23)*Y(26)
      DYDT(27)=D(3)*Y(19)+Z23*Y(26)+Z43*Y(28)-(Z34+Z35(4)+Z3(4)+D(4))
     ! *Y(27)
      DYDT(28)=D(3)*Y(20)+Z34*Y(27)-(Z43+D(4))*Y(28)
      DYDT(29)=D(3)*Y(21)+Z35(4)*Y(27)+Z15(4)*Y(25)-(D(4)+Z52)*Y(29)
      DYDT(30)=Y(25)/B
      DYDT(31)=Y(26)
      DYDT(32)=Y(29)/B

c      DO 10 I=1,11
c        IF(ABS(Y(I)).LE.TINY)THEN
c          DYDT(I) = 0.
c        ENDIF
c 10   CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE ODEINT(Y,NVAR,X1,X2,EPS,H1,HMIN,NOK,NBAD)
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (MAXSTP=50000,NMAX=32,TWO=2.0,ZERO=0.0,TINY=1.E-20)
      COMMON /PATH/ KMAX,KOUNT,DXSAV,XP(200),YP(NMAX,200)
      DIMENSION YSCAL(NMAX),Y(NMAX),DYDX(NMAX)
C     WRITE(*,*) 'MADE IT TO ODEINT'
      KMAX = 0
      X=X1
      H=SIGN(H1,X2-X1)
      NOK=0
      NBAD=0
      KOUNT=0
      DO 11 I=1,NVAR
        Y(I)=Y(I)
11    CONTINUE
      XSAV=X-DXSAV*TWO
      DO 16 NSTP=1,MAXSTP
        CALL DERIVS(NVAR,X,Y,DYDX)
        DO 12 I=1,NVAR
          YSCAL(I)=ABS(Y(I))+TINY
12      CONTINUE
        IF(KMAX.GT.0)THEN
          IF(ABS(X-XSAV).GT.ABS(DXSAV))  THEN
            IF(KOUNT.LT.KMAX-1)THEN
              KOUNT=KOUNT+1
              XP(KOUNT)=X
              DO 13 I=1,NVAR
                YP(I,KOUNT)=Y(I)
13            CONTINUE
              XSAV=X
            ENDIF
          ENDIF
        ENDIF
        IF((X+H-X2)*(X+H-X1).GT.ZERO) H=X2-X
         CALL RKQC(Y,DYDX,NVAR,X,H,EPS,YSCAL,HDID,HNEXT)
       IF(HDID.EQ.H)THEN
          NOK=NOK+1
        ELSE
          NBAD=NBAD+1
```

```
      ENDIF
C     WRITE(*,*) NUC,X
      IF((X-X2)*(X2-X1).GE.ZERO)THEN
        DO 14 I=1,NVAR
          Y(I)=Y(I)
14      CONTINUE
        IF(KMAX.NE.0)THEN
          KOUNT=KOUNT+1
          XP(KOUNT)=X
          DO 15 I=1,NVAR
            YP(I,KOUNT)=Y(I)
15        CONTINUE
        ENDIF
        RETURN
      ENDIF
      IF(ABS(HNEXT).LT.HMIN) PAUSE 'Stepsize smaller than minimum.'
      H=HNEXT
16    CONTINUE
      PAUSE 'Too many steps.'
      RETURN
      END
C
C
C
      SUBROUTINE RKQC(Y,DYDX,N,X,HTRY,EPS,YSCAL,HDID,HNEXT)
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NMAX=32,FCOR=.0666666667,
     *  ONE=1.,SAFETY=0.9,ERRCON=6.E-4)
      DIMENSION Y(NMAX),DYDX(NMAX),YSCAL(NMAX),YTEMP(NMAX),YSAV(NMAX),
     1DYSAV(NMAX)
      PGROW=-0.20
      PSHRNK=-0.25
      XSAV=X
      DO 11 I=1,N
        YSAV(I)=Y(I)
        DYSAV(I)=DYDX(I)
11    CONTINUE
      H=HTRY
1     HH=0.5*H
      CALL RK4(YSAV,DYSAV,N,XSAV,HH,YTEMP)
      X=XSAV+HH
      CALL DERIVS(N,X,YTEMP,DYDX)
      CALL RK4(YTEMP,DYDX,N,X,HH,Y)
      X=XSAV+H
      IF(X.EQ.XSAV)PAUSE 'Stepsize not significant in RKQC.'
      CALL RK4(YSAV,DYSAV,N,XSAV,H,YTEMP)
      ERRMAX=0.
      DO 12 I=1,N
        YTEMP(I)=Y(I)-YTEMP(I)
        ERRMAX=MAX(ERRMAX,ABS(YTEMP(I)/YSCAL(I)))
12    CONTINUE
      ERRMAX=ERRMAX/EPS
      IF(ERRMAX.GT.ONE) THEN
        H=SAFETY*H*(ERRMAX**PSHRNK)
        GOTO 1
      ELSE
        HDID=H
        IF(ERRMAX.GT.ERRCON)THEN
          HNEXT=SAFETY*H*(ERRMAX**PGROW)
        ELSE
          HNEXT=4.*H
        ENDIF
      ENDIF
      DO 13 I=1,N
        Y(I)=Y(I)+YTEMP(I)*FCOR
13    CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE RK4(Y,DYDX,N,X,H,YOUT)
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NMAX=32)
      DIMENSION Y(NMAX),DYDX(NMAX),YOUT(NMAX),YT(NMAX),DYT(NMAX),
     1DYM(NMAX)
```